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JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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33 West Thirty-ninth Street, New York

American Welding Society

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JOURNAL

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AMERICAN WELDING SOCIETY
ESTABLISHED 1919
JOURNAL

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ANNUAL MEETING OF AMERICAN WELDING SOCIETY

The annual meeting of the Society, held on April 22, 23 and 24, marks another milestone of progress in the affairs of the Society.

The report of the Director of the research department of the Society (American Bureau of Welding), brought out strikingly the progress made in this direction. There are fewer committees than in former times but the projects are larger and of greater importance. The Bureau has become a dominant factor in cooperative welding research in this country. On the other hand, the possibilities for still greater service are enormous, as is also the possibilities in the field of private research by individual companies and the development of welding patents by them.

The popularity of the annual dinner, which as yet is the only social event of the annual meeting of the Society, is indicated by the attendance. An opportunity to get together at a time when there is no serious business at hand is very much appreciated and the officers of the Society hope to provide still greater opportunities for "play" as well as "work" at the fall meeting in Boston.

One of the outstanding features of the annual program is the inspection trip. Fortunately the Society was able to arrange a trip through the Bayway Plant of the Standard Oil Company. Those that were able to go on this trip were well repaid for the time that was spent. A complete description is given elsewhere in this JOURNAL. As announced in previous issues, the technical session was devoted to a symposium on the two general subjects.

1. Inspection and testing of welded products in a wide variety of industries, and
2. Checking and testing the skill of welding operators to perform these different jobs.

Papers were secured from a number of industries. Unfortunately there was not enough time left for the discussion of these papers and as it was announced at the meeting, the Meetings and Papers Committee would welcome a careful critical review of these papers and the discussion of any or all of them by every member of the Society. The first series were printed in the April issue of the JOURNAL and the remainder will be printed in the June issue.

It seemed to be the general consensus of opinion of the authors that in the past too much responsibility was placed upon the welder, as in many cases the design, selection of materials and methods of technique were left in his hands. At the present time the tendency is to hold the operator responsible only for the manipulation of the torch or electrode; the other factors being governed by designers, engineers and the research laboratories. Methods of inspecting and testing the work differ with each industry. A number of important changes were made in the standing committees of the Society. In the Meetings and Papers Committee, Mr. R. L. Shepherd of the *Electrical World* replaces Mr. K. H. Condit, who has found it necessary to resign. In the Membership Committee, Mr. C. A. McCune, who has recently been promoted by the American Chain Company to the post of Research Director, has resigned and has been replaced by Mr. J. J. Flaherty, formerly of the Boston Elevated Railway, and now Sales Engineer of the Page Steel and Wire Company. Mr. C. A. McCune continues to serve as Treasurer of the Society.

INSPECTION TRIP

A party of about ninety members went to Newark by the Hudson and Manhattan tubes, where they were met by two large public service buses provided by the Society. The party was conveyed to the Bayway plant of the Standard Oil Company in Eliza-

Members of the American Welding Society on inspection

beth and were divided into two groups, one going to the shops and the other to the "field." The trip was under the direct supervision of Mr. W. G. McCullam, assistant general superintendent of the Bayway refinery. In the boiler shop, tanks, drums and other containers are sheared, rolled, punched, riveted and welded. At the time at which the inspection party went through 2-in. plates were being rolled into drums 6 ft. in diameter and 40 ft. long. The drums are called soaking drums and are used in the process of "cracking" the crude oil. The drums are made of alternate large and small diameter sections, the difference in diameter being twice the thickness of the plates, the larger sections are shrunk on the ends of the smaller sections and then riveted. After being riveted the fillets are arc-welded and the job is tested by hydraulic pressure to 750 lb. per sq. in. The working pressure of this apparatus is about 350 lb. per sq. in. at several hundred degrees temperature. It is also interesting to note that the longitudinal seam is double vee welded for a distance back from the edge equal to the depth of building on the heads before the heads were riveted into place.

In the welding shop we saw small tanks being fabricated and repaired, and a great deal of general repair and maintenance work. Both electric and oxy-acetylene were being extensively used here. Outside of the welding shop we saw huge stills being riveted. Here, as in the case of the soaking drums, all the caulking edges were electric welded to insure tightness. All fittings, nozzles, etc., were riveted to the still and then welded to insure tightness.

The field welding shop afforded an excellent opportunity to study the oxy-acetylene welding process. Headers were fabricated out of wrought iron pipe by notching out an end and bending the remaining edges together and welding them up. Then holes were cut in the side of the pipe and from six to ten flange connections welded in. These headers were held in a jig during the welding and the flange connections were strapped in place and then tacked and welded.

The method employed at the Bayway plant on a header made of 6-in. pipe, about 12 ft. long, having 11 4-in. outlets, is to prepare the 6-in. pipe, cutting the hole to the outlets, beveling the edges for welding, scalloping the ends of the pipe for closure and then clamping the header pipe to a heavy 12-in. I beam. The outlets with flanges attached are lined up on top over their respective openings and clamped to a steel plate, which holds the flanges horizontally and at a uniform level. The welder starts, say, at one end, welds an outlet and then skips to another, welds that, back to another outlet, and so on until finished. In other words, he does not weld the outlets in rotation, as they have found the springing or warping is reduced by not localizing the heat too long in one space.

When the job is finished, the clamps are released and the header allowed to take its natural position. If it springs up too much it is heated at the proper point and drawn down to the I beam again and allowed to cool. In substantially this manner they are able to make practically perfect jobs so far as observation showed.

The crude still batteries furnished another striking example of the desirability and adaptability of welding. As the gases accumulate from the dis-

trip to Bayway Plant, Standard Oil Co., Elizabeth, N. J.

tillation process they are led off in large pipes. These hot vapor lines were formerly made up of pipe flanged and bolted together. Now, however, the practice is to weld the pipes together (the oxy-acetylene process is used here) and it not only made a neater job but it also was stronger and better in every way. The cost of the welded vapor line was materially lower than that of the flanged line and there was no trouble caused by leakage.

Another interesting example of welding came to light in the Octo Filtering Building, where Octo, a very highly refined oil for medicinal purposes, was being produced. Here all the pipe lines running from the stills were welded. The lines were manifolded so that the oil was distributed into large vats with numerous compartment sub-divisions. Here again the neatness of the welded line and the ease of manifolding and of making special fittings, etc., and longevity of the weld has demonstrated its superiority.

Probably one of the most unusual and remarkable examples of engineering skill was evidenced in the 6-in. internal fire tubes used in the oil stills. The joints in these tubes are made by silghtly expanding the end of one tube and forcing the other (of equal diameter) into it. This process is done with a special hydraulic ram designed by the Standard Oil engineers and capable of exerting a pressure of 40 tons per sq. in., which is the pressure required to force the two tubes together. The second tube is forced into the first for a distance of several inches and then the external lap is electric welded at the caulking edge. It has been found that this joint will outlast any other previously employed and is very simple to make.

Welding at the Bayway plant is at a very high state of development and has increased remarkably during the last year and a half. All welding is performed under careful supervision and time schedules are prepared for each standard job.

WELDED RAIL JOINTS

The portion of the Journal that is usually devoted to technical papers, items and reports in this issue is given over entirely to the third progress report of the welded rail joint committee.

Very few of our members realize the enormous amount of work that is being done by the various research committees of the Society. We urge that all members read this report carefully, as much valuable information is contained therein. The street railway industry is one of the largest users of welding. It is hoped that through the efforts of the committee an improvement will be brought about in making joints which will result in a greater life of the joint and incidentally in the saving of millons of dollars annually to the street railways.

PAPERS TECHNICAL SESSION

A number of the papers presented at the technical session of the annual meeting of the Society were printed in the April issue of the Journal. The remainder will be printed in the June issue.

This editorial is to urge all members of the Society to study these papers very carefully and to send in a discussion of any or all of them.

FALL MEETING TO BE HELD IN BOSTON

At the meeting of the Board of Directors held during the annual meeting of the Society, it was decided to hold the fall meeting in Boston.

Several new features are to be tried out at this meeting. An exposition will be staged at the Massachusetts Institute of Technology on welding apparatus and welded products. The space is being furnished through the courtesy of the Institute, and the present plans are to have at least 20,000 people to see the exhibitions during the three days of the fall meeting. Six technical papers will be scheduled and ample time will be provided for a discussion by all those interested. Papers will be printed in advance and sent out to all members. Further details will be announced in the next issue of the JOURNAL.

PRESIDENT'S ANNUAL REPORT

It is now a year since you honored me by electing me President, and I wish to express at this time my appreciation for the many courtesies which have been extended to me throughout the year by the members at large. The service I may have rendered is not to be measured with the same yard stick as the benefits I have gained through the close association with eminent men, and I might truly say that I envy my successor.

You expect at this time some statement showing what has been accomplished during the year, and this can be based on many conceptions as to what is most important in the growth of an organization like ours. You might measure the development by the increase of membership or by the outstanding accomplishments relating to the industry, or by what service it has rendered to its members and the industries it has associated with.

The executive committee during the past year has had presented to it problems entirely different from those of previous years, and we believe it is in the solving of these problems or the arrangement for solving of these problems that we can best judge the success of the work done during the past year. The most outstanding of special problems is to be found for instance in the cooperation with the American Electric Railway's Association and other associations, in problems of welding wire specifications; the cooperation with the Tank Manufacturers Association, and the cooperation with the boiler code committee, and the American Society of Mechanical Engineers, in the drawing up of proper rules for the fabrication of boilers and pressure vessels by welding; in the formation of an educational committee with the purpose of supplying industries with reliable fundamental information in the art of welding in all its methods; the holding of welding exhibits has also been carefully considered, as have many other important matters.

In the research field the American Welding Society stands foremost among organizations of its kind. We are spending more on research per member and have to our credit more accomplishments than any other similar organization. Confirmation of this statement is readily found in the annual report of the Director of the American Bureau of Welding, Professor C. A. Adams, and we sincerely hope that in the year to come with the increased support of the welding industry this research work may be expanded, and may include not only investigations in connection with structural welding, but the many other branches of the industry which as yet have not the desired foundation on which to build.

From the financial standpoint we are today in the best condition that this society has enjoyed since its organization. Yet, while we are in good condition, it has been accomplished by refraining from carrying on work which is both needed and desirable, and it is to be hoped that much additional money will be secured in the next year to meet the proper expansion of our work.

From the standpoint of membership, a very encouraging gain has been made during the year, but not equal to that anticipated by the executive committee. Many suggestions have been made to increase the membership, the simplest one, that of each member securing another new member. Many members have to their credit the securing of one or more members, yet the larger proportion of our members have not shown any activity in this direction, which is rather strange, when it is clear that the individual member's gain to himself is vastly improved by the added strength given the society due to an increase in membership.

The meetings of the local sections at large have this year presented better programs, but in many cases even with these better programs the at-

tendance has been small. Much help can be obtained from our national organization if requests for assistance are made. Here I might suggest that at least a portion of the time at each meeting be given over to discussions on the following subjects:

A—Determining the qualifications of the welder.

B—The material and its inspection.

C—Design and layout of the material for welded joints.

D—Preparation of the material for welding.

E—Welding technique (including organization of personnel and sequence of operations).

F—Method of test of completed job and strength and tightness of welded joints.

I would also recommend that typewritten records be made of the meetings in order that such discussions as take place may be retained and copies forwarded to the National Headquarters, in order that such suggestions may be used for the benefit, not only for the members present at these section meetings, but to the members at large.

The Journal of our Society is rapidly approaching the point of being a leading publication, all to the credit of our editor, as well as to the members who have freely contributed articles for publication. It is certain that the editor would be greatly benefited in receiving reports from the sections on discussions as suggested before, as it is well known that much of value is obtained in constructive discussions.

The relations between the national headquarters and local sections have been most cordial. Much credit is due to our secretary and the section officers for maintaining these harmonious relations.

For the most part the monthly report from the sections have been very complete and can only be improved by forwarding copies of the discussions taking place at the various meetings.

We have to our credit the organization of the Detroit section of our Society, with a membership of 33 and a very large list of prospective members. The section was initiated through the efforts of local members with help of our vice-president, Mr. H. S. Mann, the director of our Chicago section, Mr. W. S. Slack, and the chairman of our membership committee Mr. C. A. McCune. While this section is the only one, it is a very healthy one. Ground has been laid for the formation of other sections which we hope will materialize this coming year.

The future of our Society appears very bright if we maintain a reasonable conservatism, increase our membership, and undertake further developments and tests, perhaps particularly connected with the use of welding in the structural field. Cooperation with the various societies with whom we are extremely friendly will produce results that will not only be gratifying but beneficial to our Society, and primarily of great benefit to our members.

In closing I wish to take this opportunity of expressing my deep appreciation to the membership at large, and to the finance and membership committee, with Mr. C. A. McCune, chairman; the by-laws committee, with Mr. A. M. Candy, chairman; the meetings and papers committee with Mr. K. H. Condit, chairman, but particularly to the members of the executive committee who have given freely of their time and effort, and who have made possible the holding of an executive meeting every month, and to one of the members of the executive committee, who is also vice-president of the welding rail joint committee, Mr. E. M. T. Ryder, who has to his credit 100 per cent attendance, and no one better than the president can appreciate what service of this kind means to the Society.

I also wish to extend to Mr. Spraragen my deep appreciation not only for what he has personally done for me as president, but for the work he has given our society as editor of our Journal, and also as a guide in our work, and last but not least I wish to express on behalf of the Society and particularly on my own behalf our appreciation to our secretary, Miss Kelly, for the wonderful work which has been done by her, and through her efforts in our office.

MEMBERSHIP REPORT

Membership	A	B	C	D	E	
April 30, 1924.....	52	201	155	275	3	686
Increase from May 1, 1924 to March 31, 1925.....	4	60	75	97		236
Total March 31, 1925	56	261	230	372	3	922
Resigned or dropped from May 1, 1924 to March 31, 1925	5	25	19	68		117
Total	51	235	210	301	3	805

Making a net gain of Class B 35
Class C 56
Class D 29

Or a total net gain of..... 120 members

Registered Attendance at Annual Meeting, American Welding Society

Adams, C. A., Pierce Hall, Harvard University, Cambridge, Mass.
Bastable, M., Wilson Welder & Metals Co., Hoboken Bldg., Hoboken, N. J.
Ball, S. S., M. W. Kellogg Company, Jersey City, N. J.
Bates, C. W., Philadelphia Electric Co., 1000 Chestnut St., Phila., Pa.
Beck, W. J., American Rolling Mill Co., Middletown, Ohio.
Bissell, A. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bleecker, W., Page Steel & Wire Co., 2629 Grand Central Terminal, New York.
Bowden, R. R., Central Steel Co., Massillon, Ohio.
Boyd, W. R., Burke Electric Co., Erie, Pa.
Bruckner, R. E., U. S. Gauge Co., 44 Beaver St., New York.
Bureau, A. G., E. G. Budd Mfg. Co., 25th & Huntingpark Ave., Philadelphia, Pa.
Card, H. S., The Welding Engineer, 608 So. Dearborn St., Chicago, Ill.
Carter, G. O., The Linde Air Products Co., 30 East 42nd St., New York.
Campbell, J. A., Rail Welding & Bonding Co., 30 Church St., New York.
Chapman, G. A., Singer Mfg. Co., Elizabeth, N. J.
Churchward, A., Wilson Welder & Mfg. Co., Hoboken Bldg., Hoboken, N. J.
Cipperly, E. J., General Electric Co., Los Angeles, Cal.
Condit, K. H., American Machinist, 10th Ave. at 36th St., New York.
Cram, R. C., Brooklyn-Manhattan Transit Co., Brooklyn, N. Y.
Crowe, J. J., Air Reduction Sales Co., Jersey City, N. J.
Davis, L. H., The Linde Air Products Co., 30 East 42nd St., New York.
DePew, E., The Welding Engineer, New York City.
D'Espies, A., Welding Service Co., 30 Church St., New York City.
Denning, G. M., Air Reduction Sales Co., 342 Madison Ave., New York City.
Donald, R. S., Thomson Electric Welding Co., New York City.
Ensworth, D., Struthers-Wells Co., New York City.
Ewertz, E. H., Bethlehem Shipbldg. Corp., Moore Plant, Elizabeth, N. J.
Farmer, E. W., A. S. M. E. Boiler Code Committee, Providence, R I.
Farmer, F. M., Electrical Testing Laboratories, 80th St. & East End Ave., New York.
Fehr, R. B., Rail Welding & Bonding Co., Cleveland, Ohio.
Flaherty, J., Page Steel & Wire Co., Bridgeport, Conn.
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Guerin, B. C., Wilson Welder & Metals Co., Hoboken, N. J.
Greene, T. W., The Linde Air Products Co., 30 East 42nd St., New York.
Hanhausen, E., M. W. Kellogg Co., Jersey City, N. J.
Hannah, R., Moore Plant, Bethlehem Shipbldg. Corp., Elizabeth, N. J.
Hecker, G. C., American Electric Railway Ass'n., 292 Madison Ave., New York.
Heinrich, H., Travelers Insurance Co., Hartford, Conn.
Heldt, F. M., Automotive Industries, New York City.
Hicks, J. F., General Electric Co., Schenectady, N. Y.
Holmes, A. W., Indiana Steel & Wire Co., Muncie, Ind.
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Hulbert, W. R., Metal & Thermit Corp., 80 Broadway, New York City.
Jacobus, D., 85 Liberty St., New York City.
Jenkins, A. F., Alexander Milburn Co., Baltimore, Md.
Keir, J. M., Union Carbide & Carbon Res. Labs., Long Island City.
Kenney, E. F., Midvale Steel & Ordnance Co., Widener Bldg., Philadelphia, Pa.
Kendall, H. B., M. W. Kellogg Co., Jersey City, N. J.
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Owens, H. T., National Gauge & Equipment Co., 51 East 42nd St., New York.
Owens, J. W., Norfolk Navy Yard, Norfolk, Va.
Peabody, H. P., J. A. Roebling Sons Co., Boston, Mass.
Plumley, S., Acetylene Journal, 53 W. Jackson Blvd., Chicago, Ill.
Powell, R. E., Western Electric Co., Chicago, Ill.
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Pritchard, C. C., Pritchard, Rumsey & Co., Inc., New York City.
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Tracey, B. C., General Electric Co., Bridgeport, Conn.
Vom Steeg, E., General Electric Co., 120 Broadway, New York City.
Vought, H., Secretary, New York Railroad Club, New York City.
Wagner, R. E., General Electric Co., Pittsfield, Mass.
Wall, H. E., Burke Electric Co., New York City.
Way, A. P., American Electric Power Co., Philadelphia, Pa.
Warner, W. L., General Electric Co., Schenectady, N. Y.
Weinman, R. A., General Electric Co., Schenectady, N. Y.
Westendarp, H., General Electric Co., Boston, Mass.
Whittemore, H. L., Bureau of Standards, Washington, D. C.
Wolfe, Jonathan, Chicago Surface Lines, Chicago, Ill.
Woofter, H. A., Thomson Electric Co., Lynn, Mass.
Wry, T. A., General Electric Co., Lynn, Mass.
Wysor, W. W., United Railways & Electric Co. of Baltimore, 1507 Continental Trust Bldg., Baltimore, Md.

SECTION ACTIVITIES

Pittsburgh

The April meeting of the Pittsburgh Section was held on the 28th in the Fort Pitt Hotel. Mr. James Burke, president of the Burke Electric Company, presented a paper illustrated with lantern slides on the subject of "Electric Arc Welding as a Manufacturing Process."

The May meeting was held on the 19th at the same place, and Mr. Russel M. Weimer of the Welded Products Company presented a paper on the "Welding of Ornamental Iron." This meeting was the last meeting of the section for this season.

New York

The last meeting of the New York Section was held in the Engineering Societies Building on Tuesday, May 12. The meeting was one of the most

successful held during the year, and about 120 people were in attendance. Through the courtesy of the American Brass Company a five-reel moving picture film, "From Mine to Consumer—A Story of Anaconda," was shown. This provided members with an opportunity to go on a conducted tour to the plants of this company and to see the various operations from the mining of the raw material to the manufacture of the finished product.

In addition, two papers were presented on the welding of cast iron with the bronze electrode. One of these, entitled "Bronze Welding of Locomotive Frames," was prepared by Mr. J. H. Chancey, blacksmith foreman on the Georgia Railroad at Augusta, and the other, "Welding with Tobin Bronze," was presented by Mr. W. C. Swift.

San Francisco

The April meeting of the San Francisco Section was held on the 22nd at the Engineers Club. The following officers were elected to serve for the coming year: Chairman, G. O. Wilson; vice-chairman, W. P. Brown; treasurer, R. H. Atkinson; secretary, W. B. Sawyer, Jr.; executive committee member (3 year term), J. C. Bennett.

Mr. W. P. Brown of the Brown Brothers Welding Company, presented a paper on "Unfired Pressure Vessels." The new welding code proposed for the State of California was also discussed.

The May meeting was held on the 15th at which time Mr. I. J. Reed, of the engineering department of the Associated Oil Company, described a very interesting installation of the laying of a pair of submarine oil pipe lines at Monterey.

Cleveland

The April meeting of the Cleveland Section was held on the 21st. The best attendance of the year was reported at this meeting. Mr. W. D. Boom, proprietor of Cleveland's largest welding shop, presented a paper on "Job Welding Problems." Mr. Boom's remarks were very interesting and to the point. The main theme of this talk was a plea to job shop owners and their employees to do every job, large or small, with the utmost thoroughness.

The May meeting was held on the 19th and was entitled "Discussion Night." The purpose of the meeting was to provide members with an opportunity to present before the meeting some particular problem that was causing trouble and to see if other members could help solve it.

Philadelphia

The April meeting of the Philadelphia Section was held on the 20th, at which time Mr. G. O. Carter, of the Linde Air Products Co., presented a report on "Construction of Trunk Pipe Lines." The following officers were elected to serve for the coming year: Chairman, P. A. L. Maurhoff; vice-chairman, A. Schroeder; secretary, H. E. Hopkins; treasurer, C. W. Bates.

Boston

The annual meeting of the Boston section was held on May 21 at the General Electric Company River Works plant at West Lynn, Mass., on May 21. About 150 people were present at the various sessions. Plenty of entertainment in the form of music, quartet and moving pictures of bathing beauties were provided. The program of the meeting was as follows:

2:00 p. m. to 3:00 p. m.—Reception of members and guests at Theatre Building and tour of inspection.

3:00 p. m. to 3:10 p. m.—Address of welcome by Nelson J. Darling, manager of River Works.

3:10 p. m. to 3:30 p. m.—Prof. C. A. Adams, "The Relation of Research to the Welding Industry."

3:30 p. m. to 3:50 p. m.—Mr. Miller, of the Back Bay Welding Co., "The Welding of Aluminum."

3:50 p. m. to 4:10 p. m.—Mr. H. O. Westendarp, Boston office of General Electric Co., "An Improved Rudder for Pleasure as Well as Merchant Vessels" (illustrated.)

4:10 p. m. to 4.25 p. m.—Mr. J. J. Crow of Air Reduction Sales Company, "Economies Through the Use of High Purity Oxygen in Cutting."

4:25 p. m. to 4:50 p. m.—Moving pictures, "Soft Coal Mining in the United States."

4:50 p. m. to 5:20 p. m.—Mr. W. L. Warner, industrial engineering department, General Electric Co., Schenectady, N. Y., "Automatic Arc Welding," illustrated with the aid of the projector machine.

5:20 p. m. to 5:35 p. m.—Concert of popular melodies by the Police Quartette.

5:40 p. m. to 6:40 p. m.—Luncheon. Concert by the General Electric Apprentice Orchestra.

6:40 p. m. to 7:00 p. m.—Moving pictures, "Hard Coal Mining in the United States."

7:00 p. m. to 7:20 p. m.—Mr. C. J. Holslag of the Electric Arc Cutting and Welding Company, Newark, N. J., "The Best Use for Electric, Gas and Thermit Welding."

7:20 p. m. to 7:40 p. m.—Mr. W. Spraragen, editor *Journal of American Welding Society*, "Why the National Research Council?"

7:40 p. m. to 8:05 p. m.—Mr. C. A. McCune, director of research, American Chain Co., Bridgeport, Conn., "The Building of the Camden and Philadelphia Bridge." Illustrated.

8:05 p. m. to 8:15 p. m.—Concert by the Police Quartette.

8:15 p. m. to 9:00 p. m.—Moving pictures.

Detroit

The Detroit Section has recently been elected into the Detroit Technical Societies. As the name implies, this is a group of all the engineering societies in the city. The club building will be used for meetings of the Detroit Section and there is no doubt but that the affiliation will prove to be mutually beneficial.

Positions Vacant

V-23. Assistant Executive. Opportunity for real live wire to connect with general repair welding and radiator works in fast growing city in north New Jersey. Established eleven years. To branch out owner needs reliable assistant executive. Capital not essential. Best location and most up-to-date equipment. Man of good personality and some experience can make unusual connection as active partner. Give particulars of past experience, age and monthly income expected.

V-24. Desires services of a young man who is familiar with welding shops in metropolitan district to sell welding rods and accessories on a commission basis with very good prospects for future development.

V-26. Wanted, a good man to sell welding and cutting apparatus.

V-27. Go-Getter wanted. Need a man to go out and get business for my welding repair works in Brooklyn, N. Y. We do electric and oxy-acetylene welding.

V-28. Electric Welders wanted for tank work. Competent welders needed for piece work. $2.90 paid for welding each 500 gallon tank. If you are interested, send in a brief statement of your qualifications.

V-29. Welder wanted. Need man that can operate arc welders and acetylene torches, to sell welding machinery and a full line of shop accessories in the Philadelphia territory. A good opportunity for a man that is looking for a future.

V-30. Salesman. Need man to demonstrate portable arc-welding machine in New York City.

Services Available

A-33. Foreman or welder desires position. Has had about thirteen years all around experience as an oxy-acetylene welder. Recently resigned from Mechanical Division, Dept. of Street Cleaning, City of New York. Was employed with the City for five years on general plant repair, automobile and other rolling equipment. Can weld aluminum, cast iron, etc., and understand preheating.

A-34. Master Welder. Expert welder desires position as assistant master welder for a railroad. Had executive experience before welding. Can make large savings in production as the result of ten years experience in welding.

A-35. Expert welder desires position. Have had 17 years experience as acetylene welder, 11 years as welder on locomotives in New York Central repair shops, 4 years as foreman of the repair of all kinds of welding and cutting in the steel car shops, one year as head repair man on all makes of welding and cutting torches and gages and one year as general welder on all kinds of work. Have also been doing electric welding as well as acetylene for the past year.

PROGRESS REPORT NO. 3 OF THE COMMITTEE ON WELDED RAIL JOINTS

A summary of Tests and Reports Since Publication of Progress Report No. 2, March, 1924

Organization:

The American Electric Railway Association and the American Bureau of Welding* united in an authoritative investigation of various types of welded rail joints in commercial use through a thoroughly representative Committee which was organized late in 1921. This Committee has a membership of about sixty individuals including Way Engineers of several of the larger street railway companies, representatives of manufacturers of welded joints and welding equipment, welding experts, scientists and testing experts.

Dr. G. K. Burgess, then head of the division of Metallurgy, Bureau of Standards, and now Director of the Bureau of Standards was elected as Chairman. Mr. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System was elected Vice-Chairman and Mr. W. Spraragen, Secretary of the Division of Engineering and the American Bureau of Welding was appointed Executive Secretary. Inasmuch as it was impossible to have this large Committee meet more than once or twice a year, the administration of the affairs of the Committee was left in the hands of a small representative Executive Committee.

Relation of American Electric Railway Engineering Association:

About $24,000 was contributed by the American Electric Railway Association, interested manufacturers, and a number of the larger street railways. The Association is acting as Treasurer for the funds. Expenditures are made upon authorization of the Executive Committee and the bills are countersigned by the Secretary and the Vice-Chairman of the Committee and by a member of the Executive Committee of the American Electric Railway Engineering Association.

Objects:

The primary object of the Committee is to improve each type of welded rail joint rather than to make comparative tests on the relative merits of the different types of joints.

Progress Report No. 1:

In order to compile a summary of the "present state of the art," a questionnaire was prepared on five types of welded joints in commercial use (cast, butt, bar, electric seam and thermit) and members of the Committee were circularized. Answers to the questionnaire were correlated and a progress report of 73 pages printed in May, 1922. Typical problems needing further investigation were also included in the report.

Preliminary Program:

It was agreed that the next step was to test out joints representing the "present state of the art" by testing joints of each type made by representative street railway companies and by the manufacturers. Tensile, drop, repeated impact, bend and conductivity tests were made on each type of joint. In order to distribute the work the Bureau of Standards made the conductivity, repeated impact, and tensile tests and also metallurgical examinations. Purdue University made the bend and conductivity tests and the University of Illinois the drop tests.

* The Bureau is the welding research department of the American Welding Society and the Division of Engineering, National Research Council.

Progress Report No. 2:

Progress Report No. 2 was published by the Committee in March, 1924. It consists of seventy-two printed pages and includes information on the organization of the Committee; instructions issued to railway companies for making up test joints for the Committee; methods of procedure and results in making tensile, bend, drop and conductivity tests; data furnished by the makers of these joints; photographs of specimens broken by the various tests and the discussion of the report.

Progress Report No. 3:

As the name signifies, this report is the Third Progress Report of the Committee on Welded Rail Joints. It does not include any of the results previously reported in Progress Report No. 2. It contains findings of the Committee, test data and other material of interest to the Committee obtained since the publication of Progress Report No. 2. Specifically it includes the remainder of results on tensile, bending and drop tests made on specimens to determine the present state of the art. The first results obtained from the repeated impact testing machine, as well as preliminary tests on the telemeter, are recorded at this time. In addition, there is also included the report of the joint examination sub-committee which carefully examined macroscopically and microscopically broken specimens; and the report of the Sub-Committee on Development whose function it is to draw up a program to test out the variables which affect the quality of the seam welded type of joint.

TENSILE TESTS

For a description of the test procedure followed by the Bureau of Standards in making these tests the reader is referred to pages 4 to 6 of Progress Report No. 2 of the Committee on Welded Rail Joints. Further comments of the Bureau of Standards on Test Procedure and the Results of Tests are given below.

Bureau of Standards Report:

On each specimen under tension, strain gages were used of the Howard type, using a gage length of 20 inches. The instruments were placed across the joint and were arranged as follows: Gage No. 1 was located on the rail base under the lip; Gage No. 2 on the rail lip; Gage No. 3 was placed on the rail head; Gage No. 4 on rail base below the rail head. The instruments were placed as near as possible to the edge of the respective parts (see photograph Figure 1). In the case of cast welds and other joints having projections of the base, Gages No. 2 and 3 only were used.

Referring to the various stress-strain curves, the curve of specimen No. 5–7 (seam weld) may be taken as a somewhat typical curve. For this specimen all four gage lines show a gradual curvature to the right and indicate that the various gage elements were undergoing extension as the load was applied to the rail section.

In some instances certain of the gage lines indicated compression or a similar phenomenon, which might be indicated by a reduced elongation on some particular gage line as referred to the other gage lines on the same rail joint. This phenomenon is shown in specimen No. 2–1 (seam weld), where the extension on gage elements 2 and 3 shows the rather typical extension, while gage element 1 shows the reduced extension, and its counterpart, gage element 4, has been actually thrown into compression as is indicated by the curve of gage line 4 sloping to the left of the vertical.

As a rule, the deformation load curves have smooth curves through the observed points. In a number of instances, however, where there have been rather peculiar irregularities the curves were drawn point to point through the observed points without any attempt to produce a smooth curve. This latter process emphasizes all irregularities and possibly might be misleading unless in the analy

sis of the various types of joints it is recognized that the general action of the joint as represented by a smooth curve more nearly explains what takes place. It is suggested, therefore, that in the comparison with the various joints the smooth curve be considered rather than the broken curve shown in some instances.

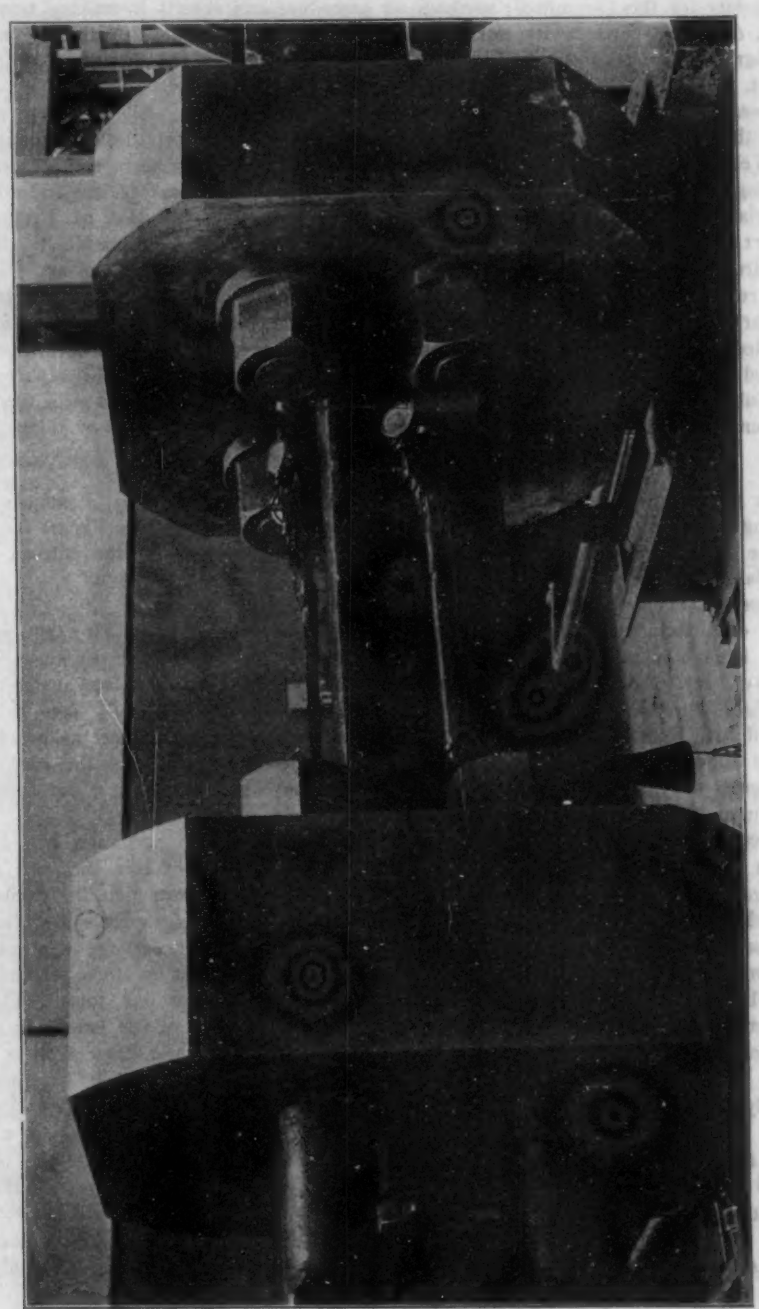


Fig. 1 — Making tensile tests on welded rail joint specimens.

Fig. 1 — Making tensile tests on welded rail joints

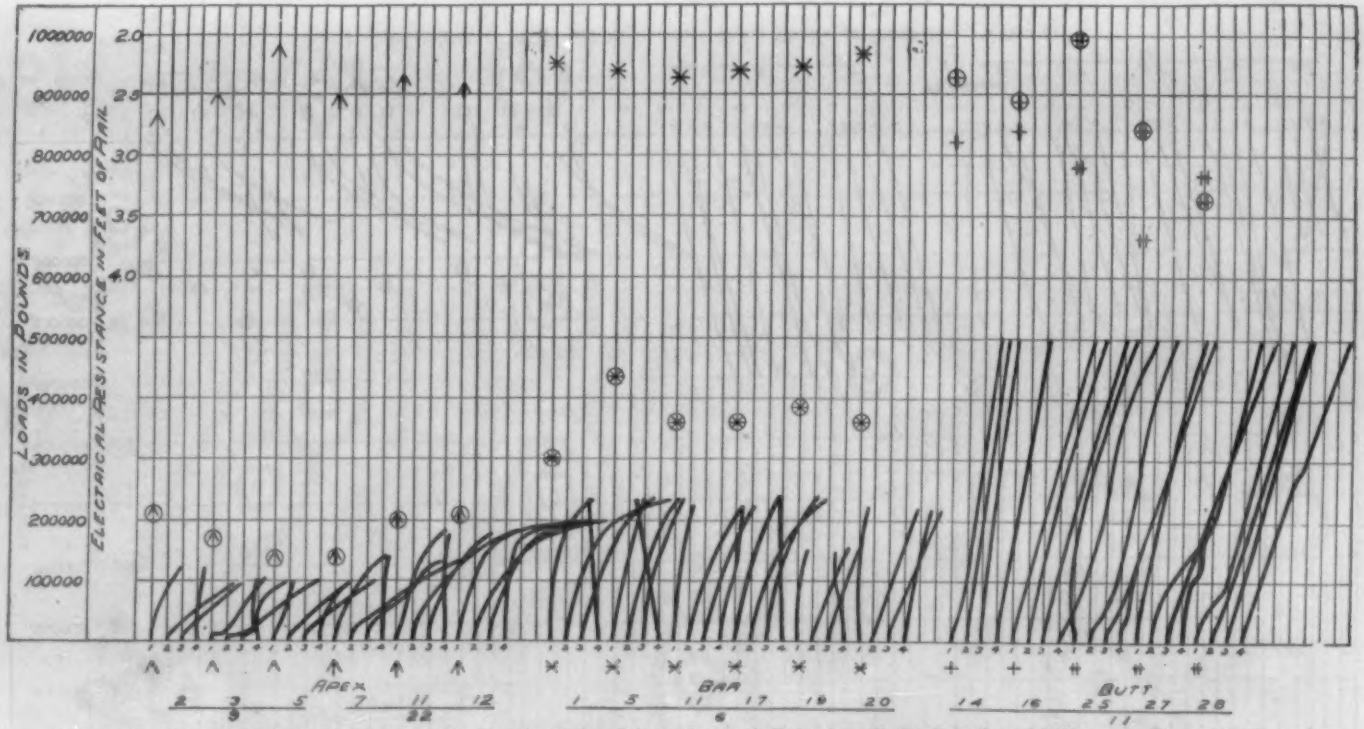


Fig. 2 — Heavy Lines Indicate Extension in 20" Length of Test Joint. Scale of Extension 1" Horizontal=4 Divisions on Plan=.02" Extension. Small Numbers Below Datum Line are Reference Numbers to Individual Extensometers. No. 1 on Rail Base on Lip Side. No. 2 on Rail Lip. No. 3 on Rail Head. No. 4 on Rail Base, Head Side. Symbols in Circles Indicate Ultimate Strength in Pounds and are Located Above No. 1 Extensometer Readings. Symbols not in Circles Indicate Electrical Resistence in Feet of Rail. Points of Arrows and Centers of Other Symbols are at Points Plotted. Numbers Below Horizontal Lines are Key Numbers Indicating by Whom Series of Joints were Made. Numbers Above Horizontal Lines are Individual Joint Numbers in the Series.
Tensile Tests on "State of the Art," Series of Joints, February 1925. Sheet 1 of 4.

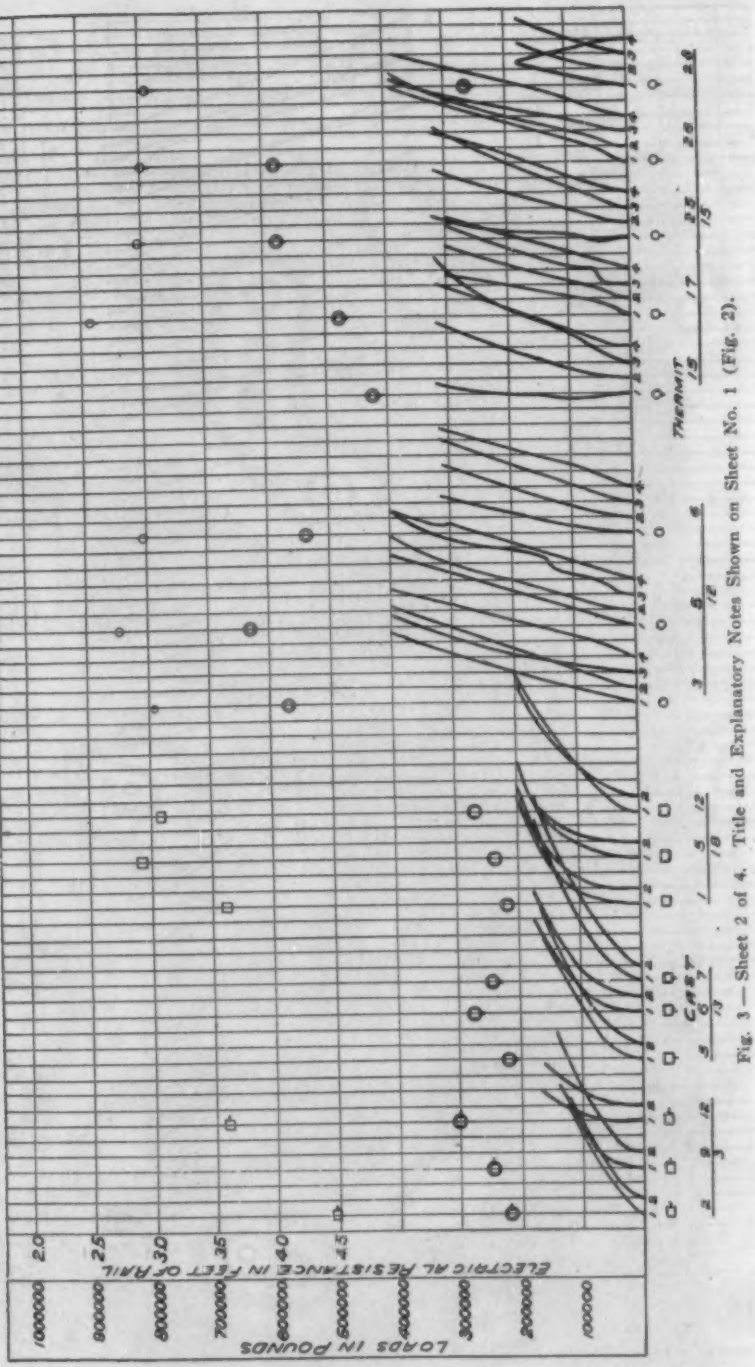


Fig. 3 — Sheet 2 of 4. Title and Explanatory Notes Shown on Sheet No. 1 (Fig. 2).

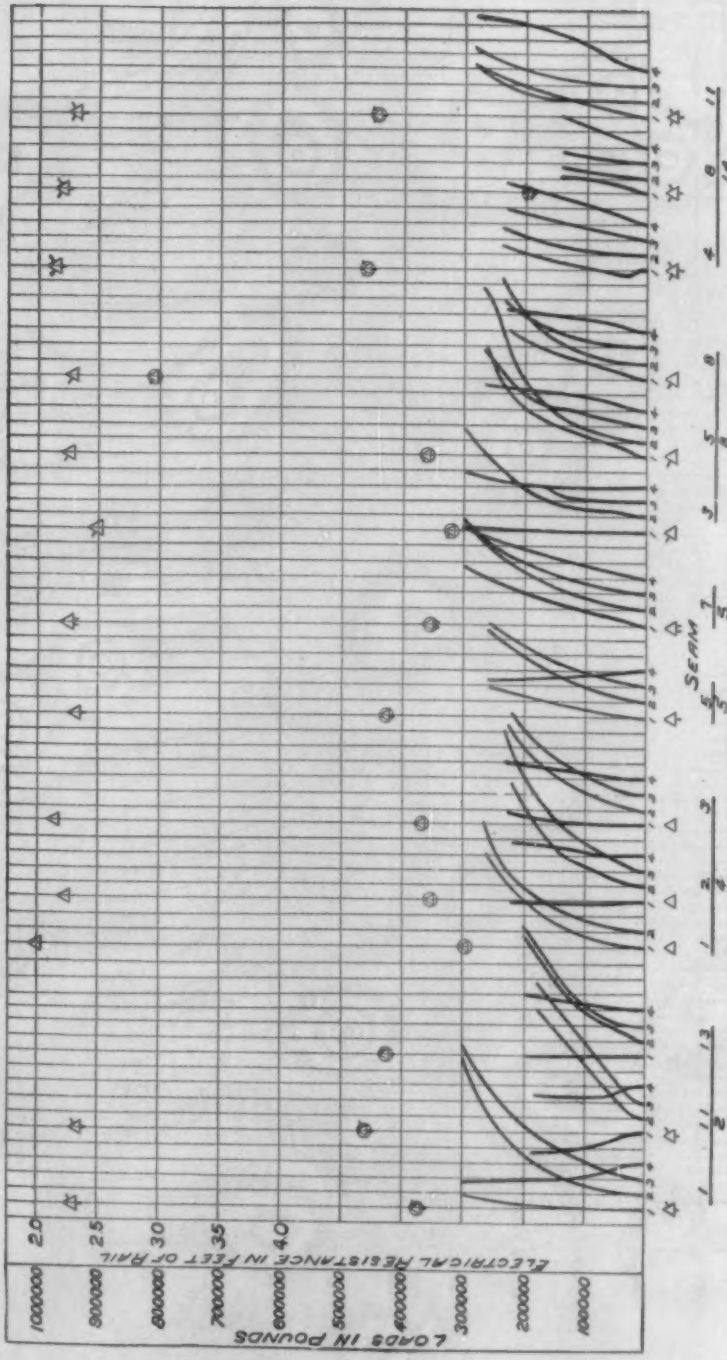


Fig. 4 — Sheet 3 of 4. Title and Explanatory Notes Shown on Sheet No. 1 (Fig. 2).

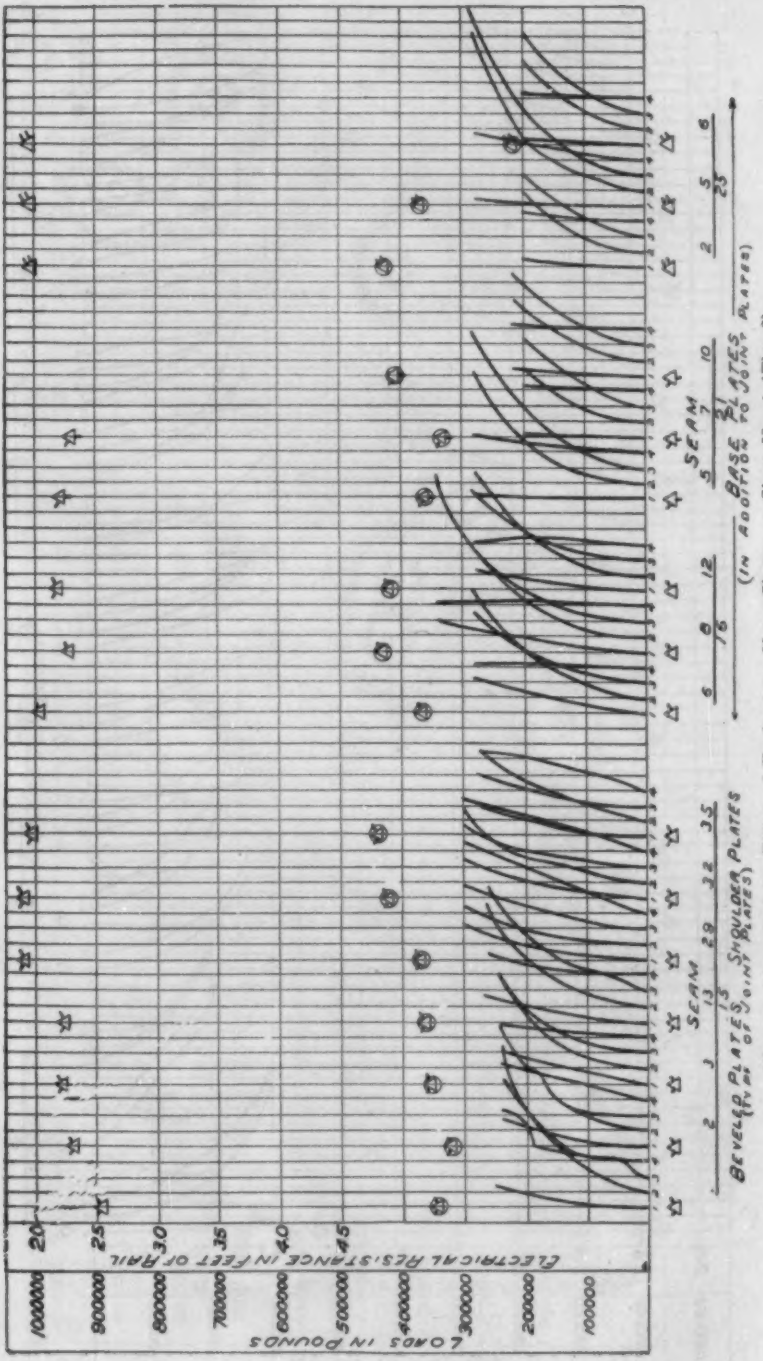


Fig. 5 — Sheet 4 of 4. Title and Explanatory Notes Shown on Sheet No. 1 (Fig. 2).

Examples of badly broken curves are those for specimens 11–27 and 11–28 (butt welds), and 15–1 and 15–2 (seam welds). Such irregularities as shown on these curves are exceedingly hard to explain. They may indicate premature failure which the gage has been able to pick up but which was not noticeable to an ob-

Fig. 6.—Bar welded joint made by the Public Service Railway Co. of Newark. Broken by tensile test.

server. It may be possible that some of these irregularities were due to slippage in the jaws holding the rails, or it may be in particular cases that the instruments used to measure the elongation failed to function properly. We do not believe that this latter contingency, however, could cause the irregularities of the types shown in specimen 15–1 (seam weld).

In order to make a complete study of the action of the joints under tensile test with the use of the load extension curves it is really essential that the center

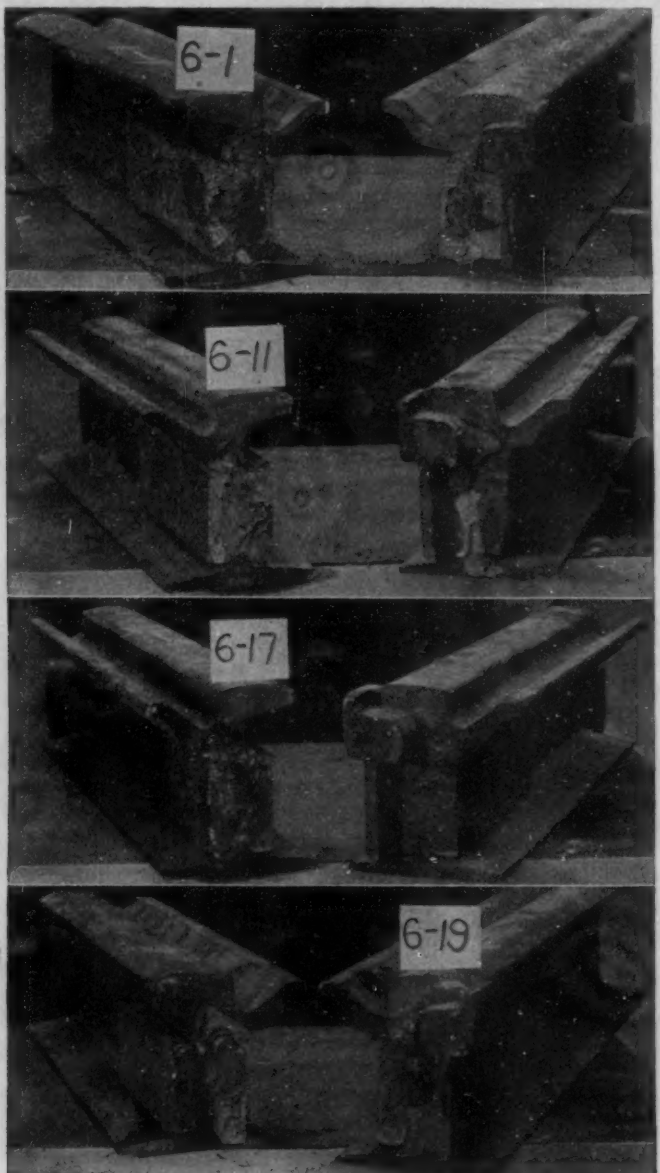


Fig. 7 — Bar Joints Made by the Public Service Railway Under the Supervision of Mr. Howard H. George.

of gravity of the various joint sections be known. In practically no case does the center of gravity of the joint correspond with the center of gravity of the rail. In testing these joints the wedge grips were designed to cause the center of pull to coincide with the center of gravity of the rail section and the grips

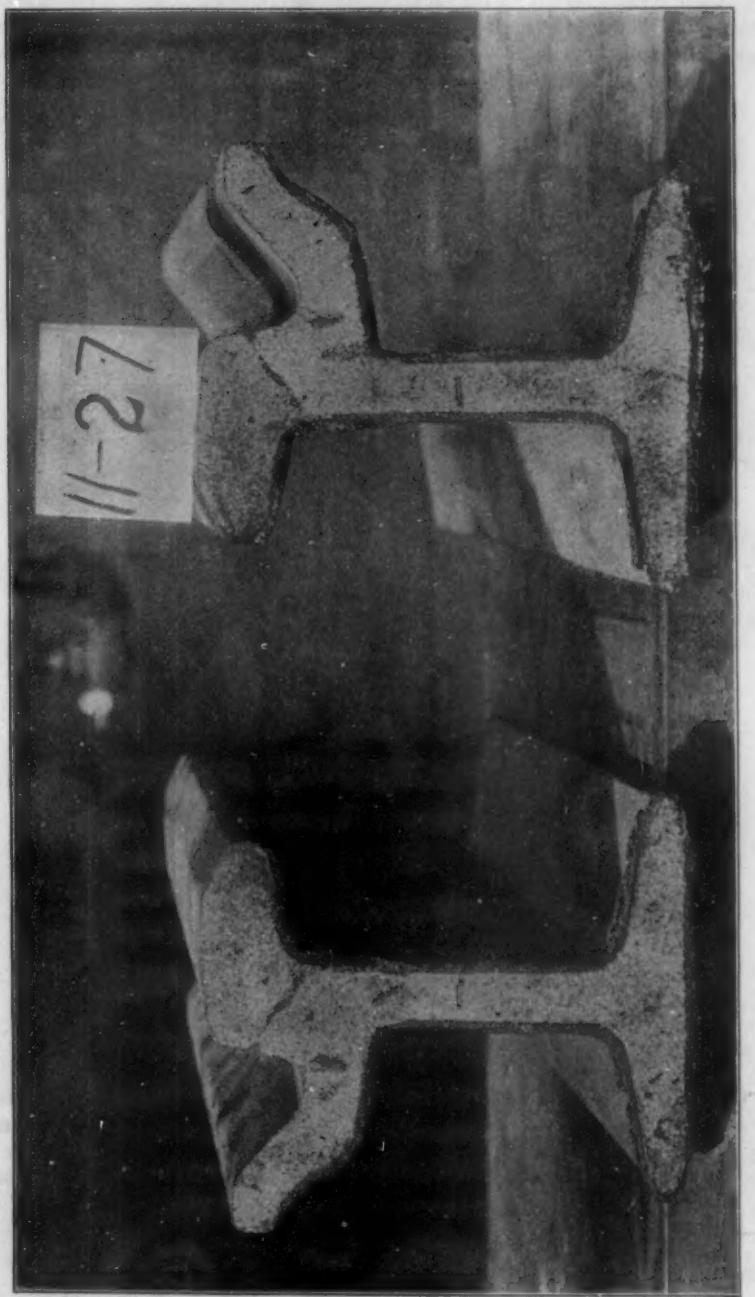


Fig. 8.—Butt welded joint made by the Lorain Steel Co. Broken by tensile test.

were carefully adjusted to produce this condition. If the center of resistance of the welded rail section does not correspond with the center of gravity axis of the rail, the joint would then be put under a bending strain during testing and a partial study of the test strain data from these tests indicates that such bending may produce serious results on the joints.

Another point that seems to need consideration, as indicated by tensile tests, is the question of starting the weld at the end of the fish plates. It is very undesirable

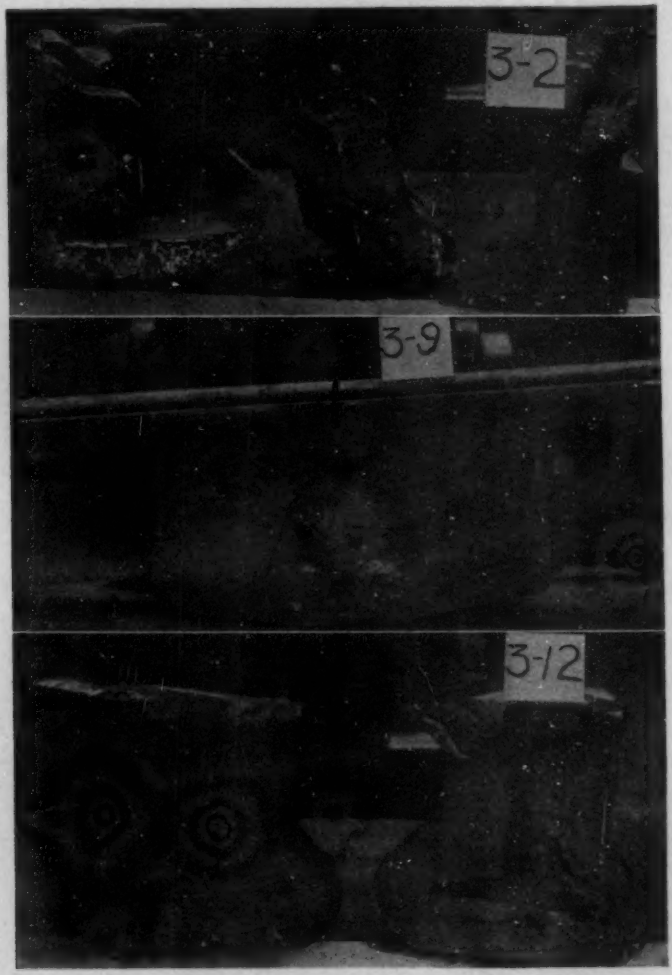


Fig. 9 — Cast Joints Made by the Brooklyn-Manhattan Transit Corp., Under the Supervision of Mr. R. C. Cram.

from the tensile tests standpoint to nick the rail section proper in starting the seam weld. This cut into the rail section seems to be almost equivalent to a saw cut in a rail section in its resultant effects. This, together with the internal stresses set up by the process of welding, caused 20 out of a total of 27 seam weld joints tested to break through the rail at the ends of the fish plate and beginning of the welding.*

* See Comment No. 1 by the Rail Welding & Bonding Company, p. 135.

In slightly more detail the following memorandum relative to the various joints has been prepared with the idea of offering assistance in interpreting the tensile test data. It must be recognized, however, that the suggestions given here are only tentative.

Fig. 10.— Cast iron welded joint made by the Milwaukee Electric Railway & Light Co. Broken by tensile test.

Joints Nos. 2–1; 2–11; 2–13. *Seam Weld:*

These joints show a greater separation at head and lip than at the base; the latter shows only slight extension or else compression. This is probably due to the rivets or bolts which connected the fish plates and web. The rivets or bolts being below the center of gravity of the rail section would produce an eccentricity of loading, in that the center of resistance of the joint would be below the center of gravity of the rail section.

Joints Nos. 3–2; 3–9; 3–12. *Cast Joint:*

The greater part of the material in this joint being below the rail center of gravity, a very rapid extension of gages 2 and 3 is to be expected.

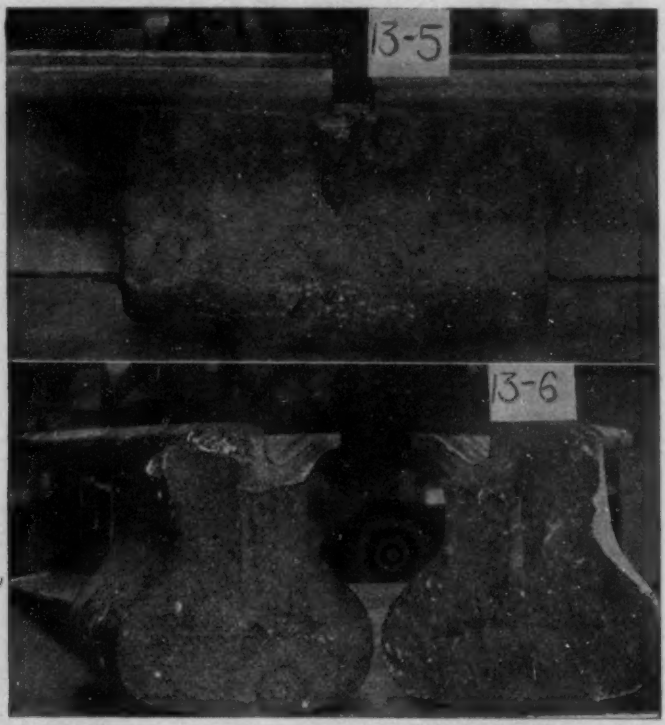


Fig. 11 — Cast Welded Joints Made by the Milwaukee Electric Railway and Light Company Under the Supervision of Mr. R. H. Pinkley.

Joints Nos. 4–1; 4–2; 4–3. *Bolts Through Fish Plates and Web:*

See comments on joints of the 2 series.

Joints Nos. 5–5; 5–6; 5–7. *Bolted Fish Plates:*

See comments on joints of the 2 series.

Joints Nos. 6–19; 6–1; 6–20; 6–11; 6–17:

The explanation of the action of these joints is somewhat doubtful. It is possible that the addition of the side bars lowers the center of gravity and also shifts it toward gage 4. If this is true, gages 2 and 3 would be expected to show about an equal extension, with gages 1 and 4 showing little tension or else compression. To check this explanation determination of the gravity axes must be made.

Joints Nos. 8–3; 8–5; 8–8. *Seam Welds:*

Greater part of fish plate section probably below center of gravity of rail section.

Bending about the horizontal axis would cause gages 2 and 3 to extend while 1 and 4 showed very little extension. This is the case of 8–3.

Joints Nos. 8–5 *and* 8–8:

These joints seem to have bent in both directions with the bending of greatest magnitude about the horizontal axis.

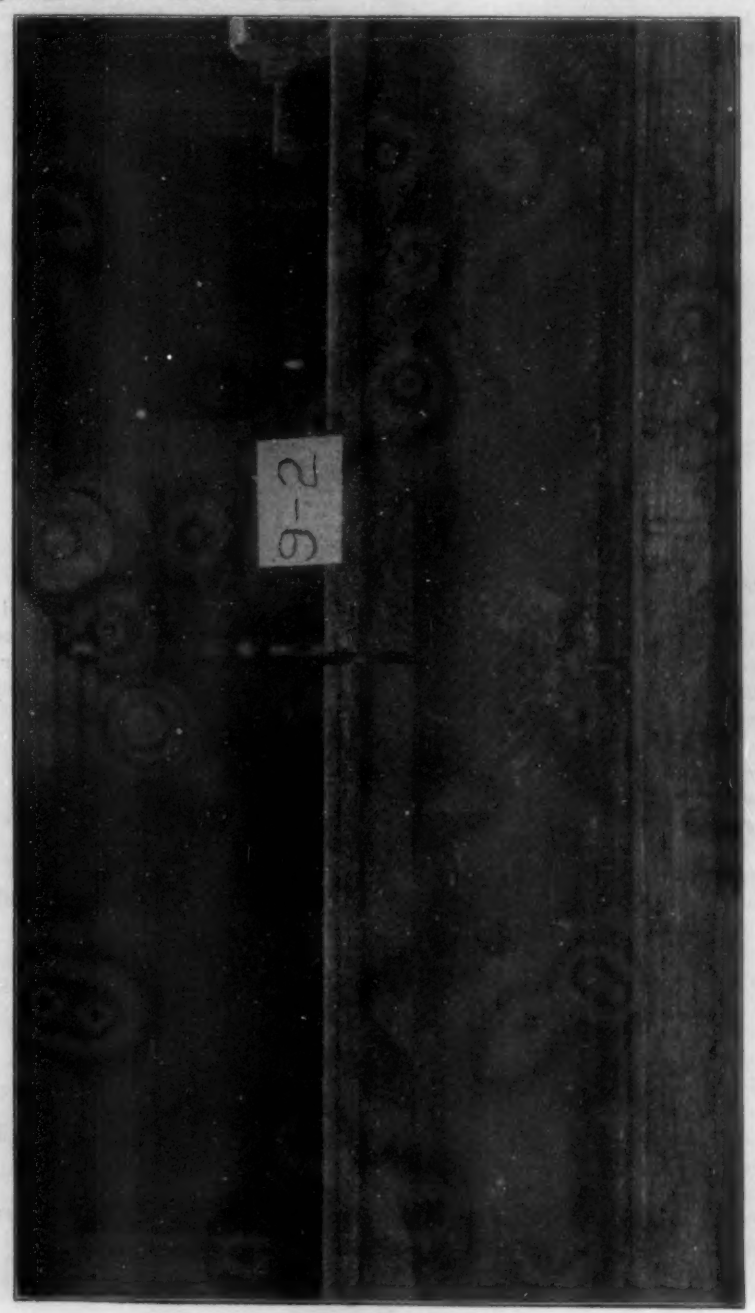


Fig. 12.— Apex joint made by the Indianapolis Switch & Frog Co., Broken by tensile test.

Joints Nos. 9–2; 9-3; 9–5. *Apex:*

Apex plates bolted through web. See comments on joints of 2 series.

Joints Nos. 11–14; 11–16; 11–25; 11–27; 11–28. *Butt Weld:*

In this series of joints the center of resistance of the joint and the center of gravity of rail are identical. It is suggested that the irregular curves obtained may be due to instrumental errors and jaw slippage, as these specimens carried a greater load than the average joints.

Fig. 13 — Apex Joints Made by the Indianapolis Switch and Frog Co., Under the Supervision of Mr. E. C. Price.

Joints Nos. 12–3; 12–5; 12–6. *Thermit Welds.*

In explaining the action of thermit joints it is suggested that the rail head be neglected as stress bearing material. This is logical, as no thermit welds tested showed complete welding of the inserts. It will then be seen that the center of resistance has been shifted from the center of gravity of the rail to a point lower and toward gage No. 1.

Joints Nos. 13–5; 13–6; 13–7. *Cast Welds:*

See comments on joints of the 3 series.

Joints Nos. 14–4; 14–8; 14–11. *Seam Welds:*

Gage No. 4 of joint 14–8 spanned a crack in the rail base. See comments on joints of 2 series.

Joint No. 15–2:

Break in curves occurring at 180,000 lb. was caused by cracks which appeared in weld at the above load.

Joints Nos. 15–1 and 15–3:

See comments on Joint No. 8–3.

Joint No. 15–13. *Seam weld:*

See comments on joints No. 8–3.

Joints Nos. 15–15; 15–17; 15–25! 15–26; 15–28. *Thermit Welds:*

See comments on joints of 12 series.

Joints Nos. 15–29; 15–32; 15–35. *Seam Welds:*

Due to the head support of the fish plates, gage 3 might be expected to show less extension than gage No. 2.

Joints Nos. 16–6; 16–8; 16–12. *Abbott:*

Abbott plates shift the center of resistance of the joint below the center of gravity of rail, causing the joint to act as Series No. 2.

Joints Nos. 18–1; 18–5; 18–12. *Cast Joints:*
See comments on joints of 3 series.
Joints Nos. 21–5; 21–7; 21–10. *Abbott:*
See comments on joints of 16 series.
Joints Nos. 22–7; 22–11; 22–12. *Apex:*
See comments on joints of 2 series.
Joints Nos. 25–2; 25–5; 25–6. *Abbott:*
See comments on joints of 16 series.

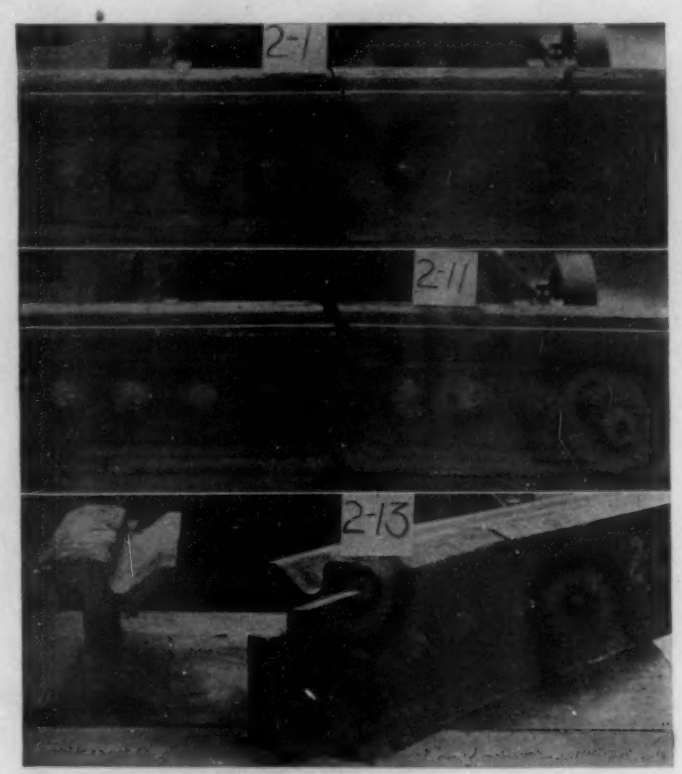


Fig. 14 — Seam Welded Joints Made by Cleveland Railway Company Under the Supervision of Mr. C. H. Clark.

Method of Failure.
Joint No.:
2–1. Rail broke at end of weld along fish plate.
2–11. Welds sheared, crack in rail flange, fish plate across mid-joint showed mill scale peeling.
2–13. Rail broke at end of seam weld.
3–2. Broke through casting, metal clean, no blow holes.
3–9. Broke through casting, metal clean, no blow holes.
3–12. Break through casting, casting clean, few blow holes near web.
4–1. Failure by shearing of seam welds.
4–2. Welds showed scaling, final failure by rail breaking at end of seam weld.

4–3. Scaling on seam welds, few shear cracks through welds, final failure by rail breaking at end of seam weld.
5–5. Rail broke at end of seam weld.
5–6. Tension failure of one bar at mid-joint through bolt hole, indications of other bar shearing.
5–7. Rail broke at end of seam weld.
6–1. Tension failure of bars at mid-joint.
6–11. Tension failure of bars at mid-joint.

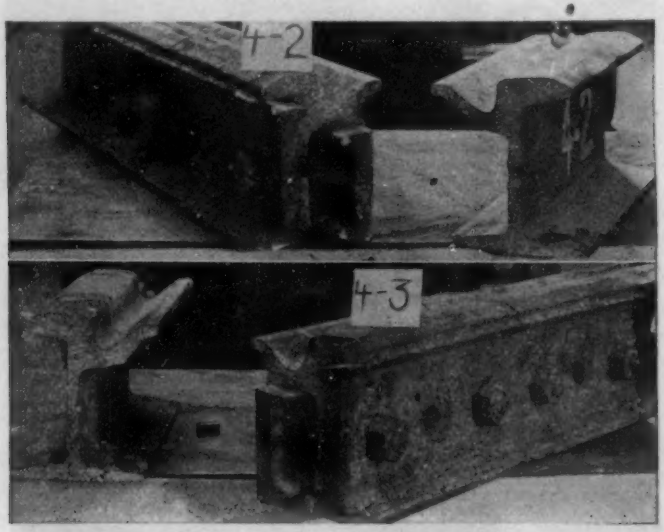


Fig. 15 — Seam Welded Joints Made by the Capital Traction Company, Under the Supervision of Mr. R. H. Dalgleish.

Fig. 16 — Seam Welded Joints Made by New Orleans Railway and Light Co., Under the Supervision of Mr. G. C. Estill.

6–17. Tension failure of bars at mid-joint.
6–19 Tension failure of bars at mid-joint.
6–20. Tension failure of bars at mid-joint.
8–3. Failure by rail breaking at end of seam weld. This break was the continuation of an old crack through one-half of the rail flange.
8–5. Seam welds sheared.
8–8. Failure by shearing of seam welds.
9–2. Failure by shearing of bolt and weld.

9–3. Failure by shearing of bolt and weld.
9–5. Failure by shearing of bolt and weld.
11–14. Broke at butt weld, rail welded over entire section.
11–16. Broke at butt weld, rail welded over entire section.

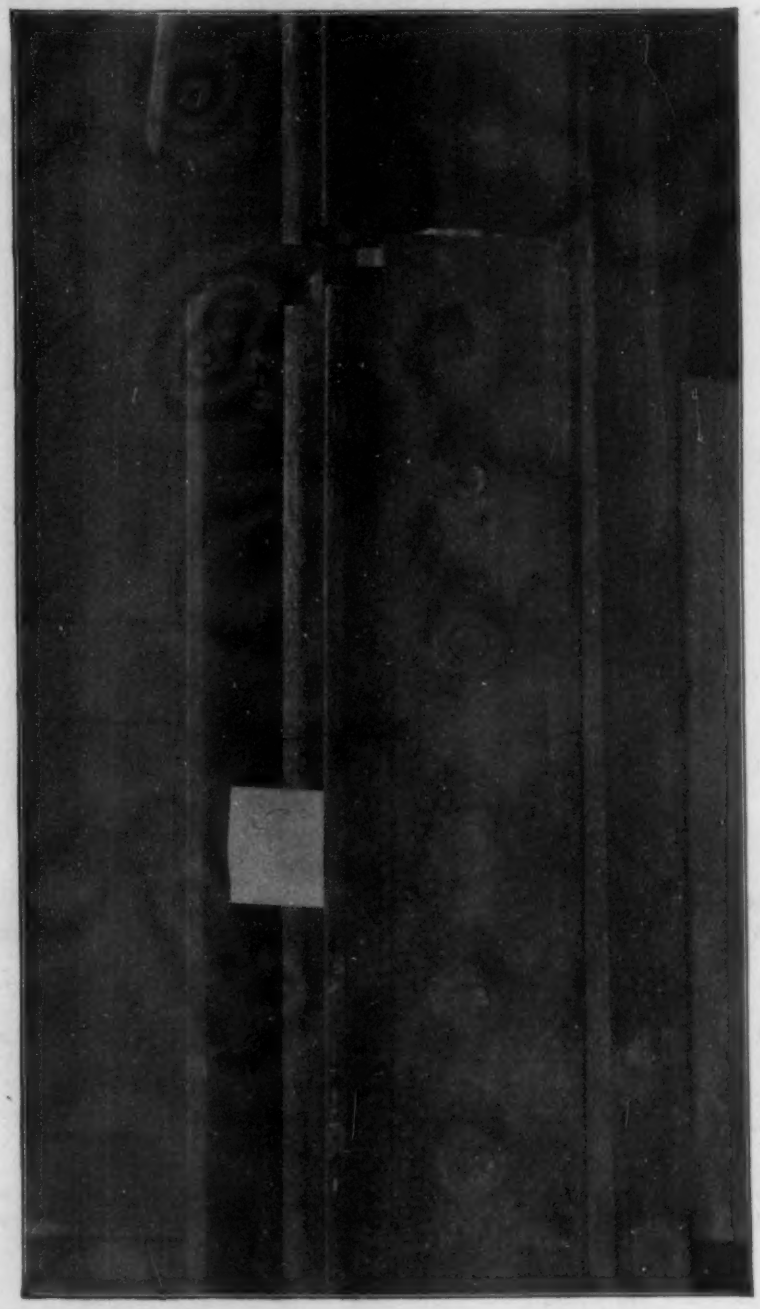


Fig. 17 — Scam welded joint No. 3-7, made by the New Orleans Railway & Light Co. Broken by tensile test.

11–25. Broke at butt weld, rail welded over entire section. Mill scale peeled off rail in free length.

11–27. Broke at butt weld, rail welded over entire section. Mill scale peeled off rail in free length.

Fig. 18 — Seam Welded Joints Made by the Montreal Tramways Co., Under the Supervision of Mr. R. M. Hannaford.

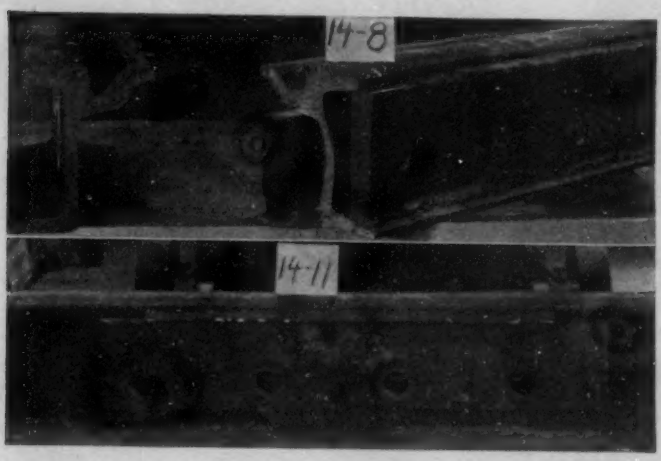


Fig. 19 — Seam Welded Joints Made by the Rail Welding and Bonding Company Under the Supervision of Mr. R. B. Fehr.

11–28. Broke at butt weld, dirty spot at base of rail lip.

12–3. Break through weld, large blow hole running diagonally across web. Insert unwelded, slag trapped under insert.

12–5. Broke through weld. Insert unwelded, slag trapped under insert, several small blow holes scattered over section.

12–6. Broke through weld. Blow holes of small size through section, part of insert welded, weld clean.

13–5. Rail pulled out of casting, no metal broken.

13–6. Break through casting at midjoint, few small blow holes, metal clean.

13–7. Failure through casting at mid-joint, metal clean.

14–4. Failure by shearing of seam weld.

14–8. Failure in rail at end of seam weld by continuation of old crack in rail base.

14–11. Failure by crack half through rail at end of seam weld from top of rail to mid web and tension failure of one fish plate at mid-joint.

15–1. Rail broke at end of seam weld.
15–2. Failure by shearing of seam welds.

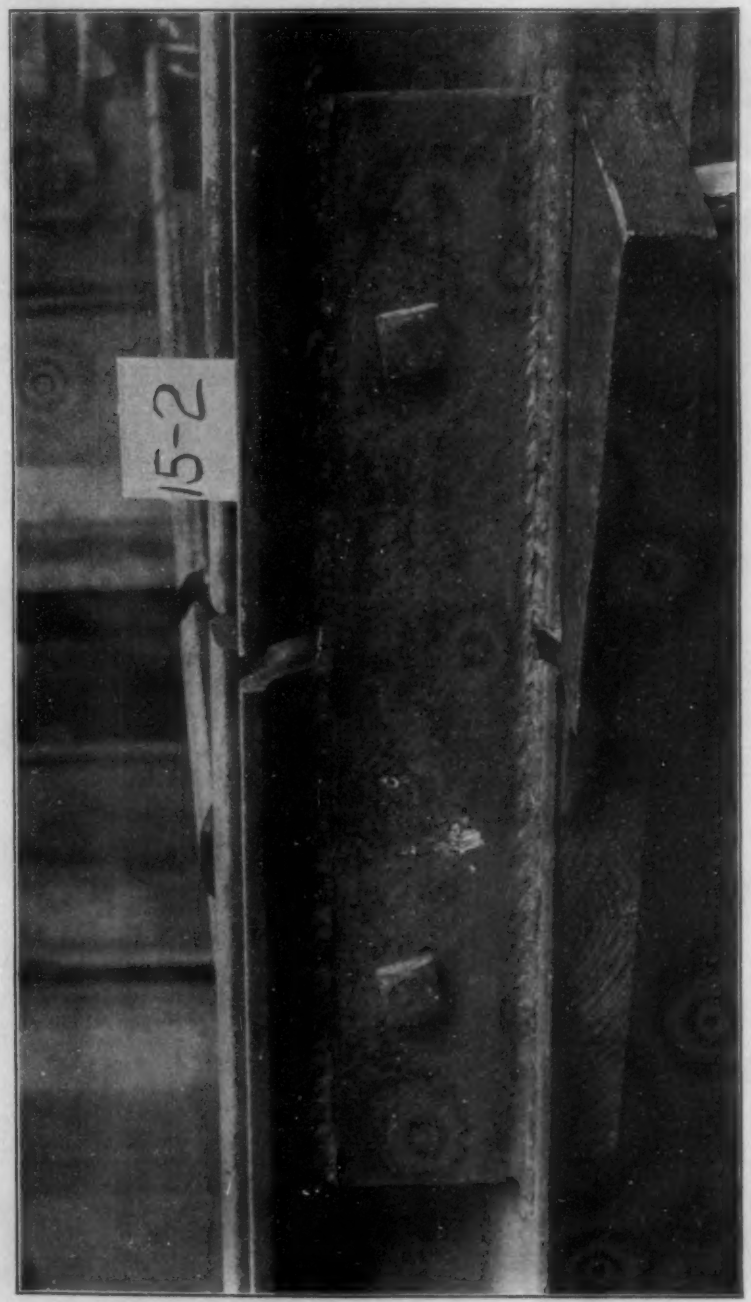


Fig. 20.— Seam welded joint made by the Third Ave. Railway system. Broken by tensile test.

15–3. Failure by shearing of seam welds.
15–13. Rail broke at end of seam weld.
15–15. Failure at junction of thermit material and rail, side of insert welded, material clean.
15–17. Rail broke through weld. Insert unwelded, blow holes under insert.
15–25. Rail broke through weld. Insert unwelded, metal clean.
15–26. Rail broke through weld. Insert unwelded, small blow holes under head.
15–28. Rail broke through weld. Insert unwelded. Blow holes throughout section.
15–29. Rail broke at end of seam weld.
15–32. Tension break in fish plate at bolt hole.

Fig. 21 — Seam Welded Joints Made by the Third Avenue Railway System Under the Supervision of Mr. E. M. T. Ryder.

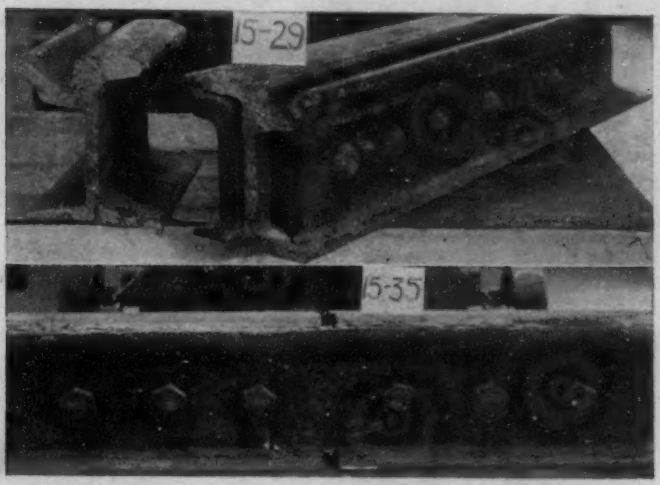


Fig. 22 — Shoulder Type of Joints Made by the Third Avenue Railway System Under the Supervision of Mr. E. M. T. Ryder

15–35. Tension break in fish plates at bolt hole.
16–6. Break in rail about 3" outside of end of fish plates.

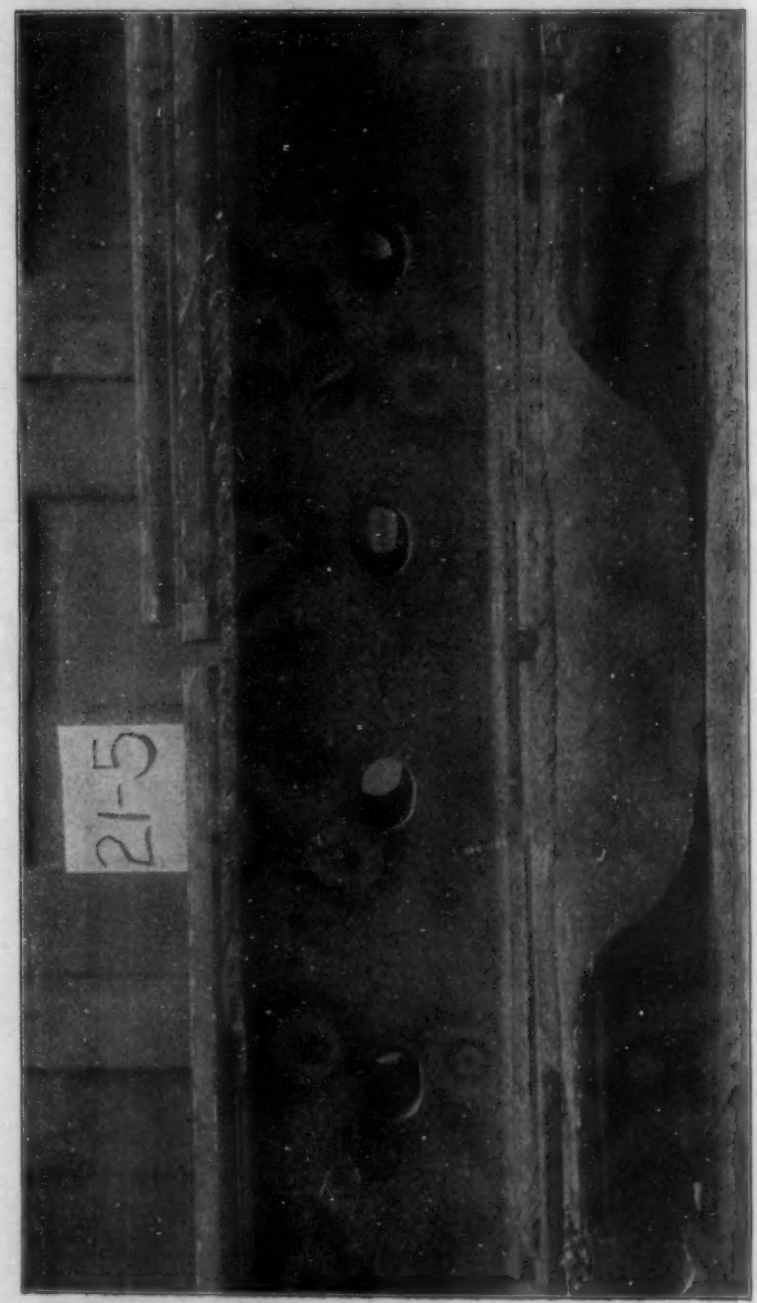


Fig. 23.— Seam welded joint with base plate made by the United Railways & Electric Co. of Baltimore. Broken by tensile test.

Fig. 24 — Seam Welded Joints with Base Plates Made by the United Railways and Electric Company of Baltimore Under the Supervision of Mr. W. W. Wysor.

Fig. 25 — Seam Welded Joints with Base Plates Made by the Liteweld Company Under the Supervision of Mr. J. C. Lincoln.

Fig. 26 — Thermit joint made by the Metal and Thermit Corporation under the supervision of Mr. J. H. Deppeler.

Fig. 27 — Thermit joints made by the Third Avenue Railway System of Mr. E. M. T Ryder.

16–8. Cracks appeared in weld under head and lip. Final failure by breaking of rail at end of seam weld.
16–12. Rail broke at end of seam weld.
18–1. Break through half of casting, metal clean.

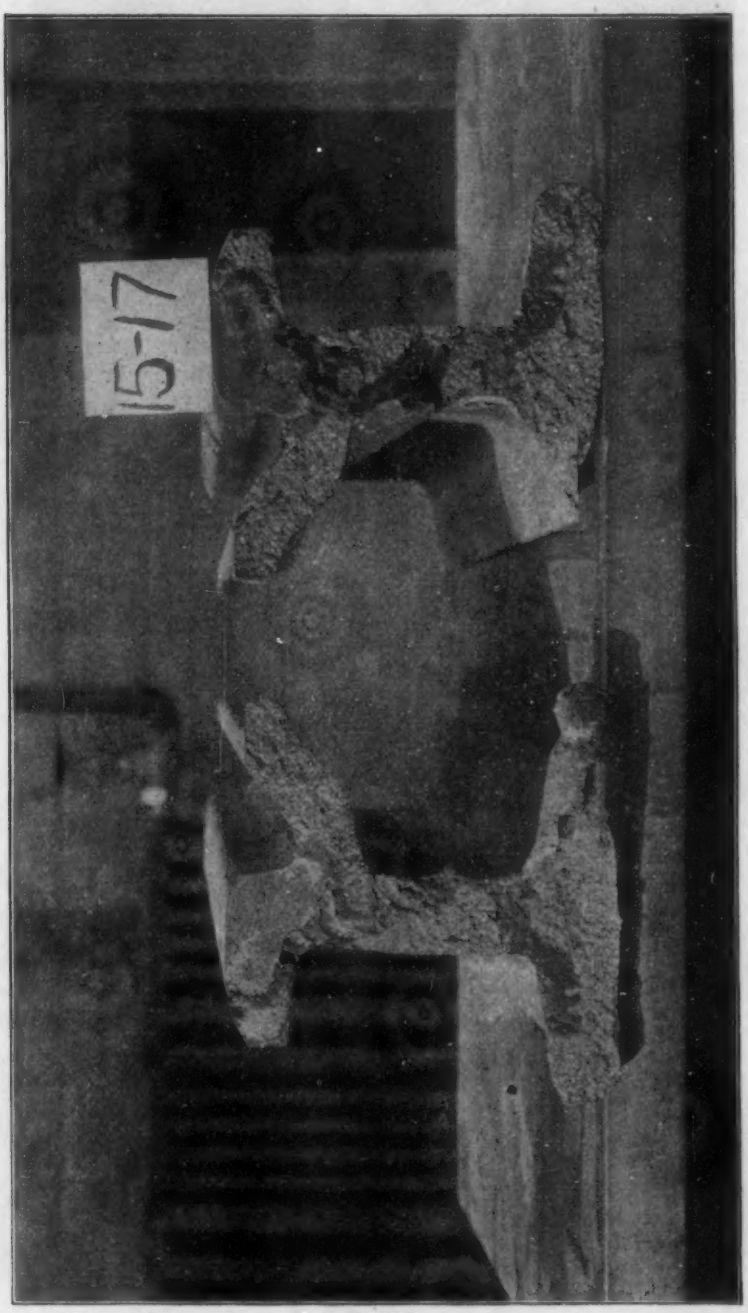


Fig. 28.—Thermit welded joint made by the Third Ave. Railway system. Broken by tensile test.

18–5. Break through casting, blow holes around web and base. Metal clean.
18–12. Break through casting, blow holes under lip and base.
21–5. Failure by shearing of seam weld at rail base and along Abbott plate.
21–7. Rail broke at end of seam weld. Partial fracture of fish plate at mid-joint
21–10. Rail broke at end of seam weld.
22–7. Failure by shearing of bolts and seam welds.
22–11. Failure by shearing of bolts and seam welds.
22–12. Failure by shearing of bolts and seam welds.
25–2. Break through rail at end of seam weld.
25–5. Rail broke at end of seam weld.
25–6. Rail broke at end of seam weld, old crack in rail base at break.

PURDUE UNIVERSITY REPORT ON BEND TESTS

NOTE.— For details as to procedure in making the bend tests see Progress Report No. 2, page 7.

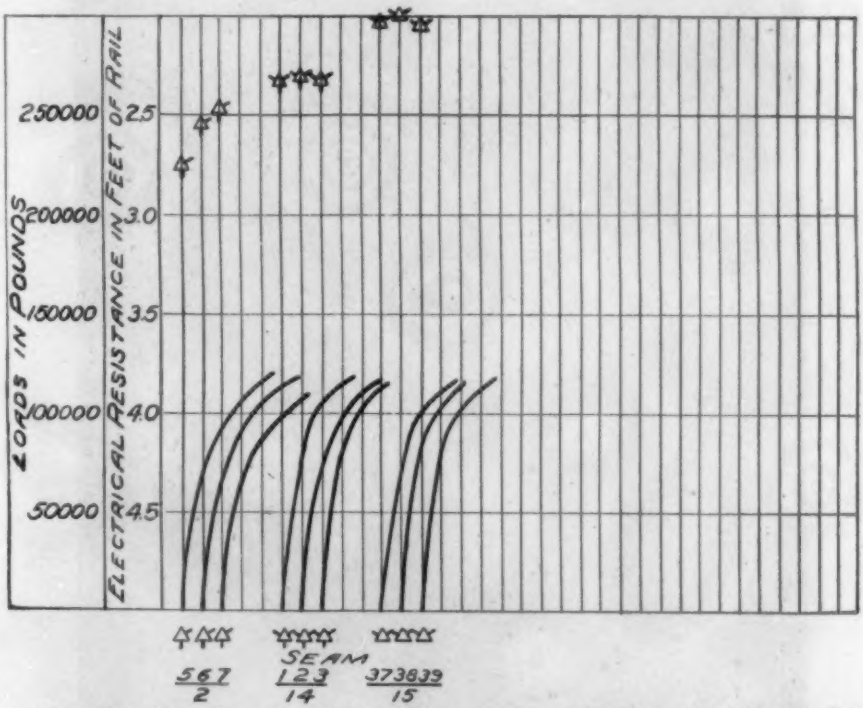


Fig. 29 — Heavy lines are deflection lines. Scale of deflections—10 divisions–1 inch Symbols give elect. resist. in ft. of rail points of arrows and centers of other symbols are at points plotted.

7–4. Both side plates yielded at joint. Sudden complete rupture of rail at end of side plates. All seams O. K. Maximum load 170,860 lbs.

7–5. Sudden complete rupture through rail at end of side plates. Fracture showed flange to be cracked from edge to web before test was made. All seams O. K. Maximum load 126,410 lbs.

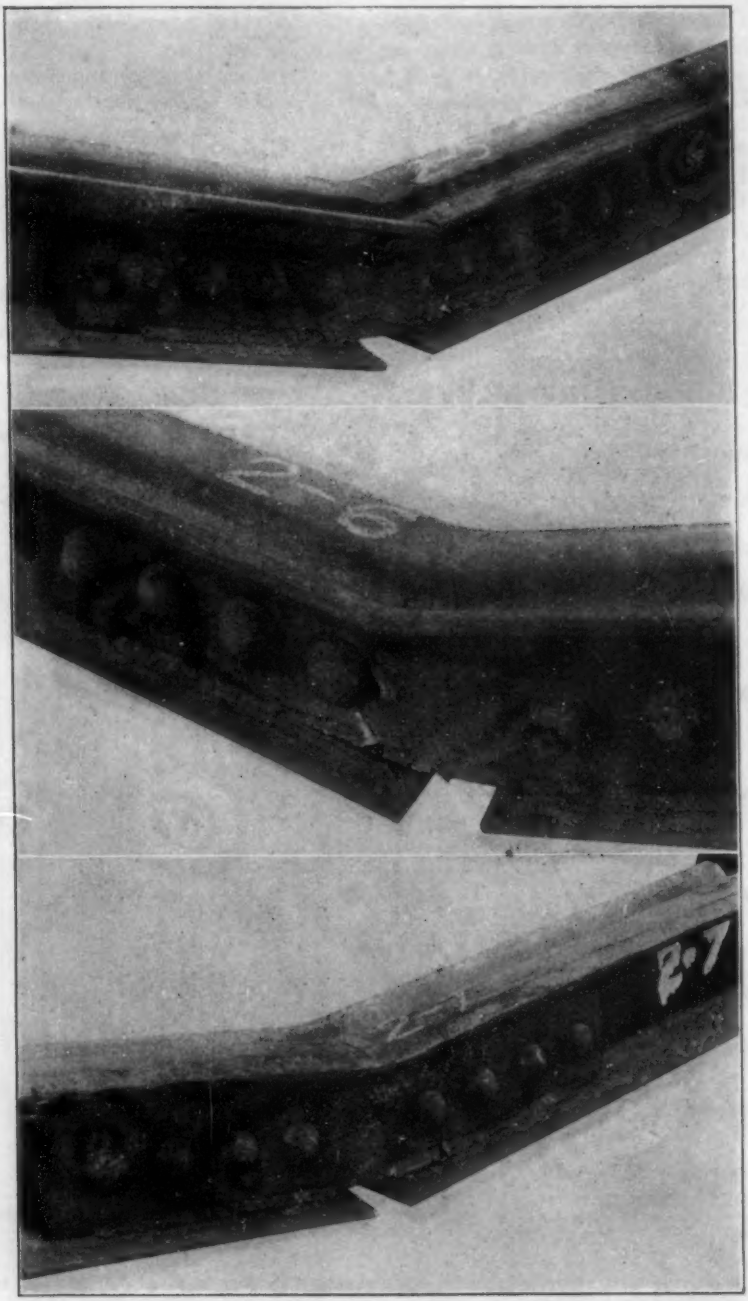


Fig. 30.— Seam welded specimens made by the Cleveland Railways Company under the supervision of Mr. C. H. Clark.

7–11. Plates yielding at 140,000 lb. load. Sudden failure in tall plate at joint, crack in rail flange at end of narrow plate, extending diagonally in web to end bolt hole. Narrow plate shows tension at 1st hole from joint. Maximum load 152,020.

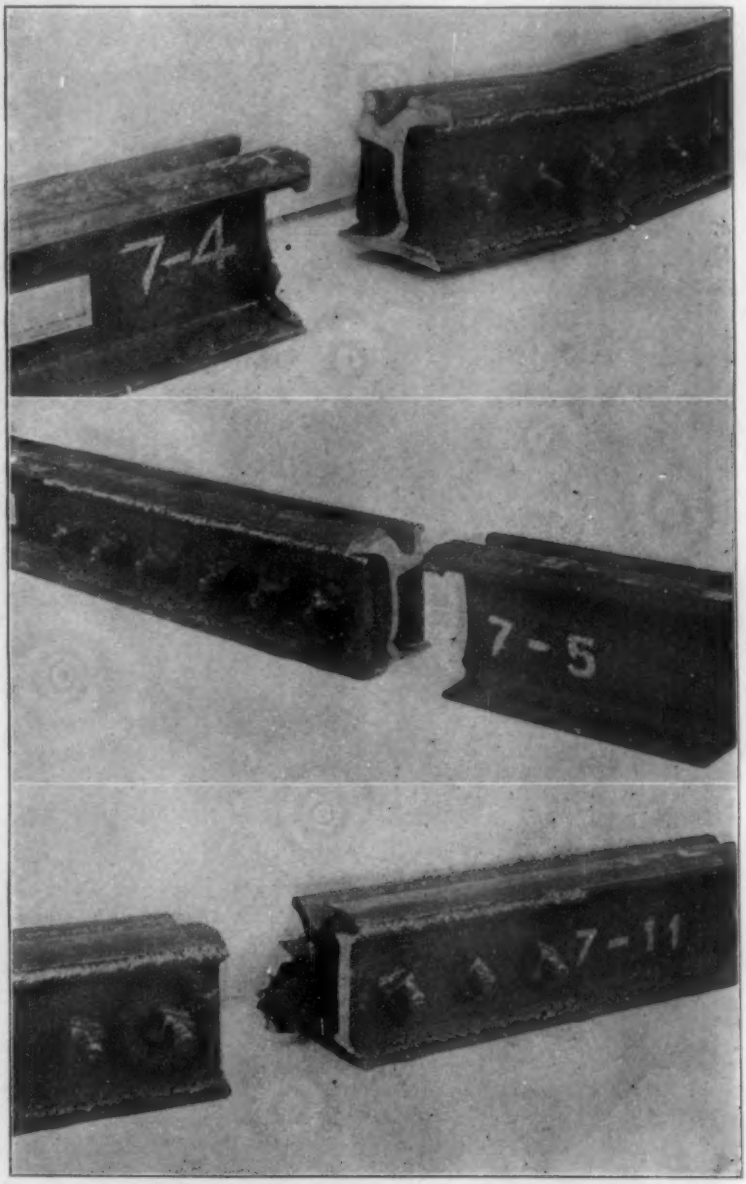


Fig. 31 — Seam welded specimens made by the Detroit Street Railways under the supervision of Mr. H. M. Gould.

15-37. Side plates yielding at 100,000 lb. load. Following maximum load tension failure in tall side plate followed by tension failure in narrow plate at 1st bolt

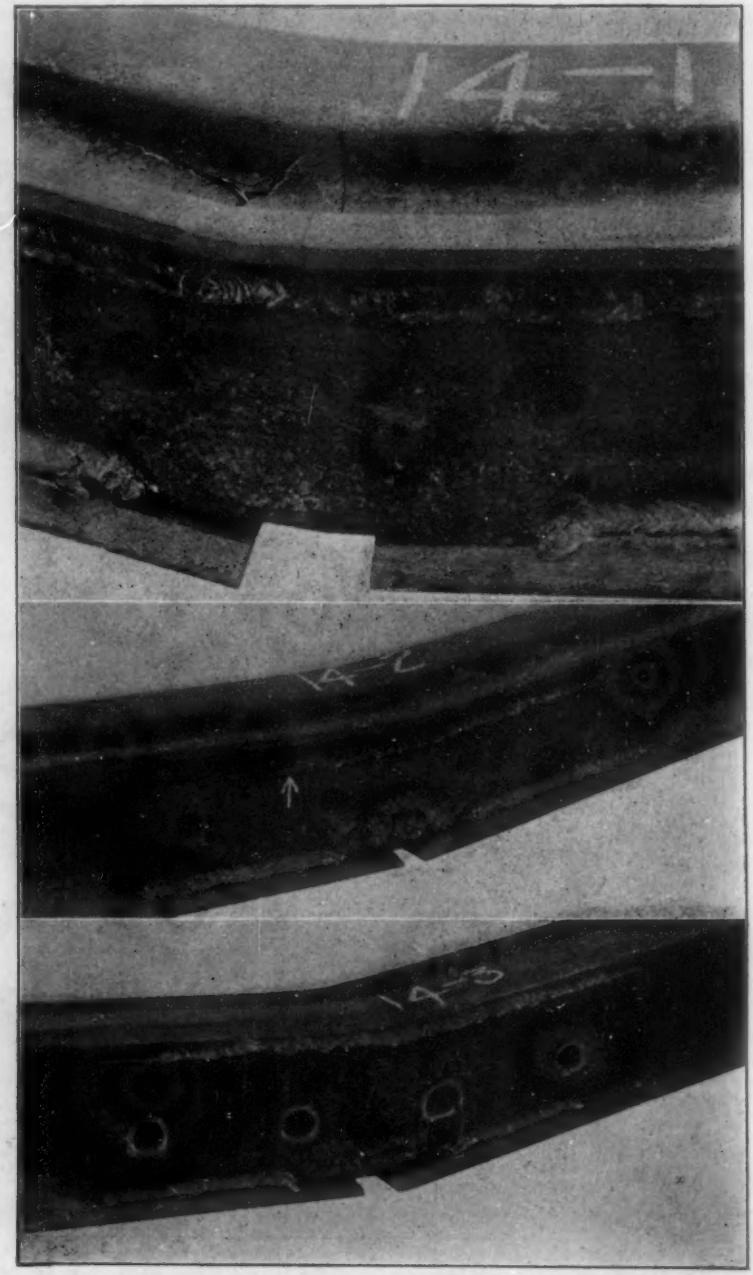


Fig. 32 — Seam welded specimens made by the Rail Welding and Bonding Company under the supervision of Mr. R. B. Fehr.

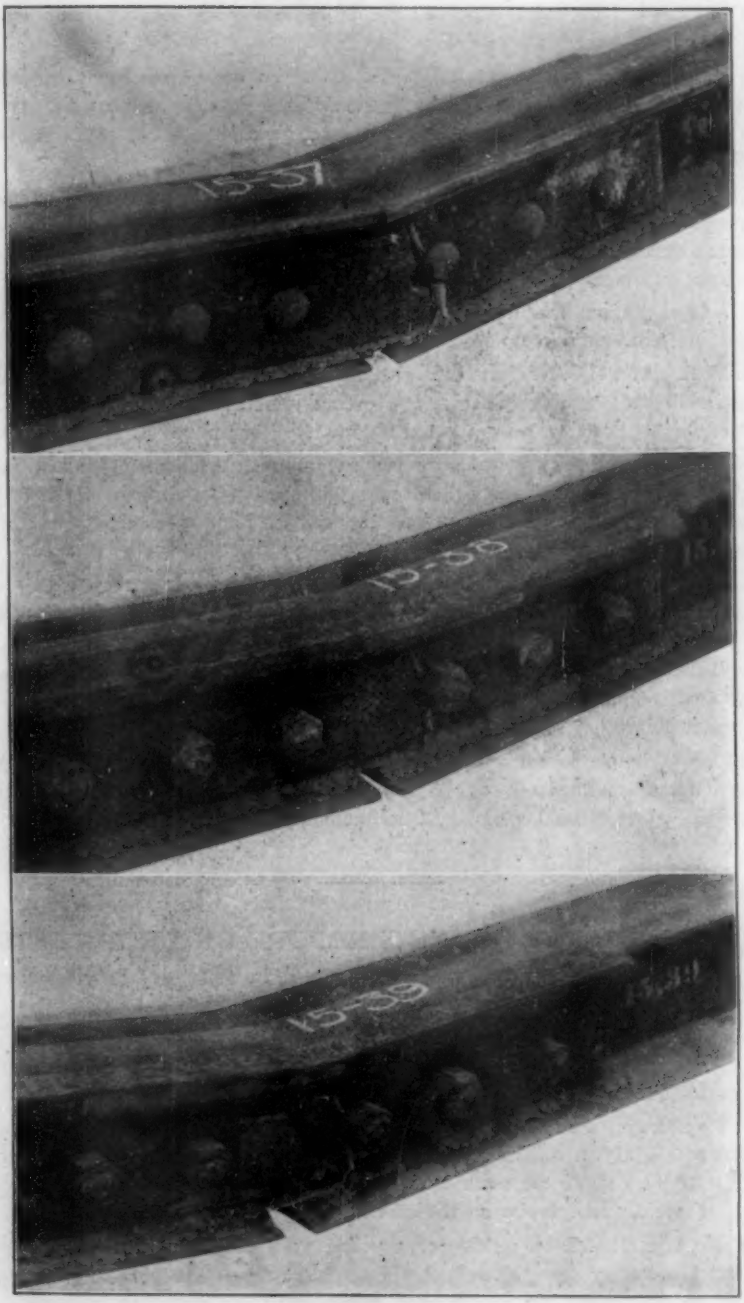


Fig. 33.— Seam welded specimens of the shoulder type made by the Third Avenue Railway System under the supervision of Mr. E. M. T. Ryder.

from joint. Flange seams opened up before maximum load. Maximum load 123,610 lbs.

15–38. Side plates yielding at 100,000 lb. load. Following maximum load tension failure in tall side plate followed by tension failure in narrow plate at first bolt from joint. Flange seams opened up before maximum load. Maximum load 129,860 lbs.

15–39. Side plates yielding at 100,000 lb. load. Following maximum load tension failure in tall side plate on both of the first bolt holes from joint, followed by tension failure on narrow plate at first bolt hole from joint. Flange seams opened up before maximum load. Maximum load 130,570 lbs.

14–1. At maximum load upper seam under lip opened up. Later, lip fractured 1½" from joint. Maximum load 168,830 lbs.

14–2. All seams O. K. just before sudden failure in rail. Failure occurred diagonally in rail, starting in flange 9½" from joint and continuing through head 5" from joint. Fracture missed bolt hole by ½". Maximum load 167,770 lbs.

14–3. All seams O. K. just before sudden failure. Wide plate, sudden failure 4" from joint. Flange failure 4½" from joint and web, through 1st bolt hole. Flange and web failures in rail on opposite end of joint from side plate failure. Maximum load 177,220 lbs.

2–5. Tall side plate scaling at joint at 90,000 lb. load. Later narrow plate yields. Gradual pulling out of both plates at first rivet from joint. Flange seams open up at 110,000 lb. load. Maximum load 160,020.

2–6. Tall side plate scaling at joint at 90,000 lb. load. Later narrow plate yields. Gradual pulling out of both plates at first rivet from joint. Flange seams open up at 110,000 lb. load. Maximum load 162,810.

2–7. Tall side plate scaling at joint at 90,000 lb. load. Later narrow plate yields. Gradual pulling out of both plates at first rivet from joint. Flange seams open up at 110,000 lb. load. Maximum load 157,020.

UNIVERSITY OF ILLINOIS REPORT ON DROP TESTS

NOTE.— For details of procedure in making drop tests see Progress Report No. 2, page 12.

Seam Welds:

2–8. Rail cracked at end of weld with first blow; crack becoming larger with the second. The rail broke on third blow at end of side plates.

2–9. No effect on weld or rail except deflection until after fourth blow when the rail cracked slightly in rail at center ½". At the end of the fifth blow the crack was 1". At the end of the sixth blow the rail cracked thru outside bolt hole on one end of weld. Rail broke on the seventh blow. Welding good.

2–10. No effect noted on welds or rail until third blow when there appeared a slight crack at center of weld on both sides. After the fourth blow the rail broke at end of side plates. Weld was in good condition.

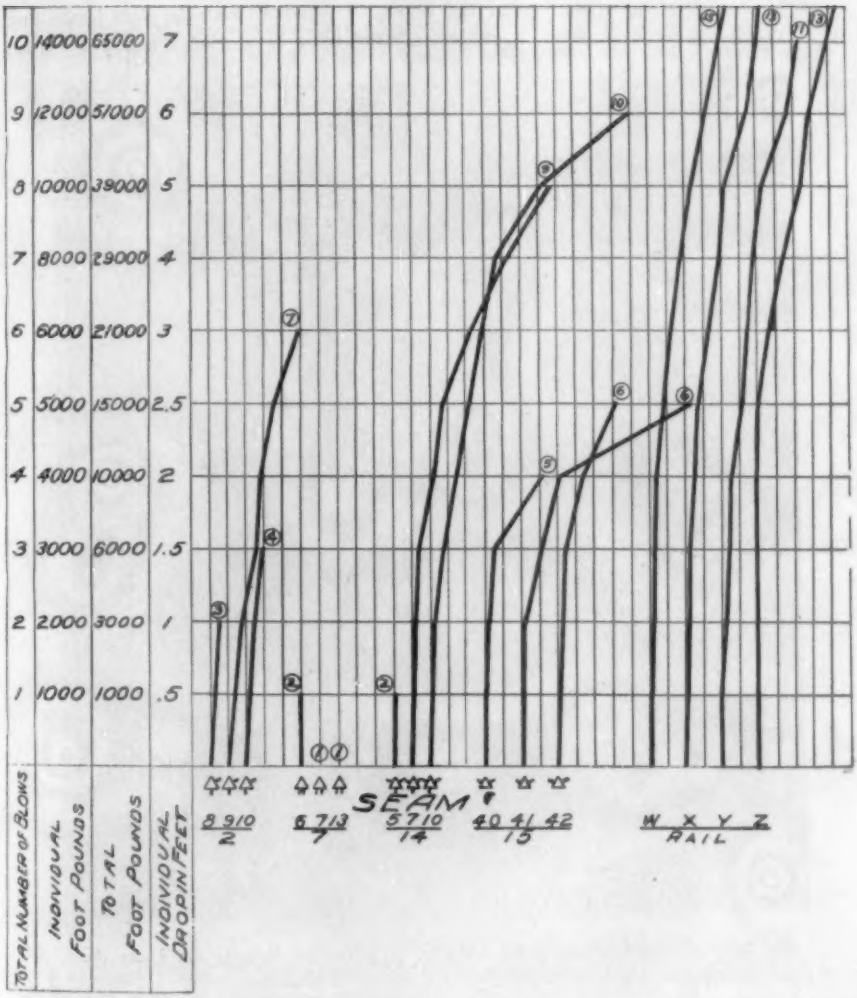


Fig 34.— Heavy lines are deflection lines scale of deflections—4 divisions–1 inch. Figures in circles (thus (5)) indicates number of blow that caused fracture.

7–6. Rail broke at first blow at end of side plates. Laboratory states welds good.

7–7. Rail broke at end of side plates and other end cracked after first blow. Laboratory states welding good.

7–13. Rail broke at first blow at end of side plates. Other end cracked. Weld good.

15–40. No effect after first blow. Slight crack at center of weld after second blow. After fourth blow two side plates broke at first (center) bolt hole. Laboratory states welding good. At the end of the fifth blow a piece of rail head broke. Welding good.

15–41. No effect noted until after the fourth blow when one side plate broke and a 2″ crack appeared in weld at center. After fifth blow rail cracked 5″ from

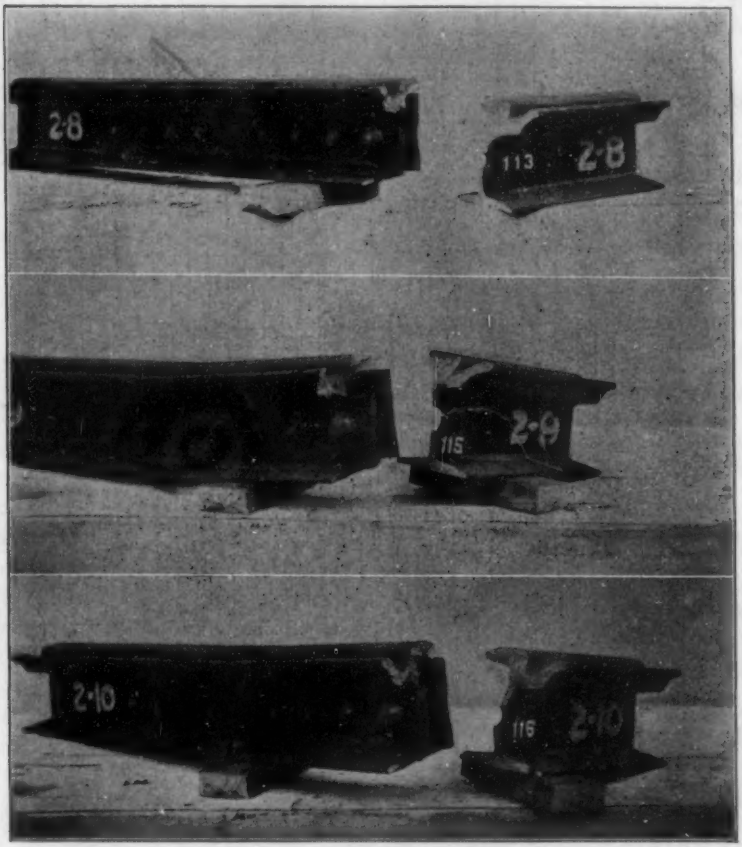


Fig. 35 — Seam welded specimens made by the Cleveland Railway Co. under the supervision of Mr. C. H. Clark.

center and both side plates were broken. Welding good. At the sixth blow the rail and side plates broke.

15-42. A very slight crack in seam at center after first blow. After fifth blow side plates broke thru inside bolt hole. At the sixth blow rail head broke. Welding good.

14–5. Rail broke at end of side plates after first blow. Welding good.

14–7. After third blow rail cracked 8″ from joint and had a slight crack in weld at base. After the fourth blow a slight break was noted in weld. After the sixth blow the side plate broke thru first bolt hole. At the seventh blow rail cracked 1½″ from joint breaking upper seam. After eighth blow head of rail cracked. Seam holding fairly well. After ninth blow both side plates broke.

14–10. Weld at two spots shows effect of bend but no break after third blow. After the eighth blow one side plate cracked thru first bolt hole. After ninth blow rail head broke—seam above broken side plates cracked. At the end of 10th blow rail broke—both side plates broke. One half of total seams good.

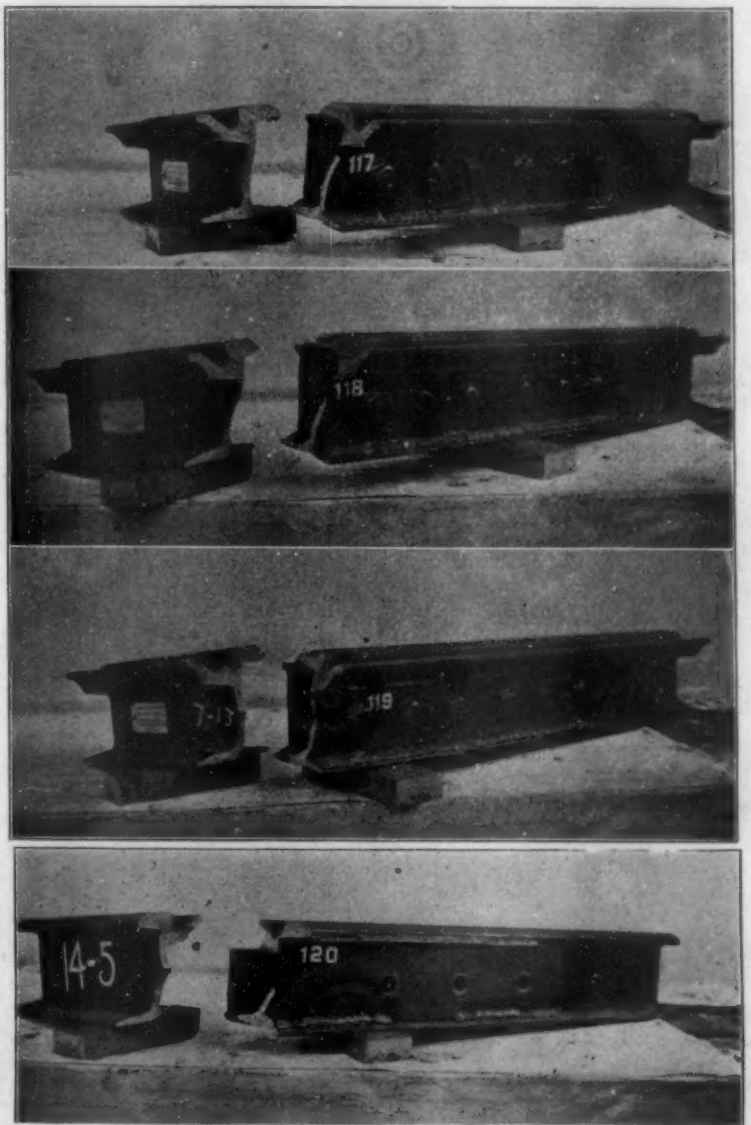


Fig. 36 — Upper three joints are seam welded specimens made by the Detroit Street Railway Co. under the supervision of Mr. H. M. Gould. Lower joint is seam welded specimen made by the Rail Welding & Bonding Co. under the supervision of Mr. R. B. Fehr.

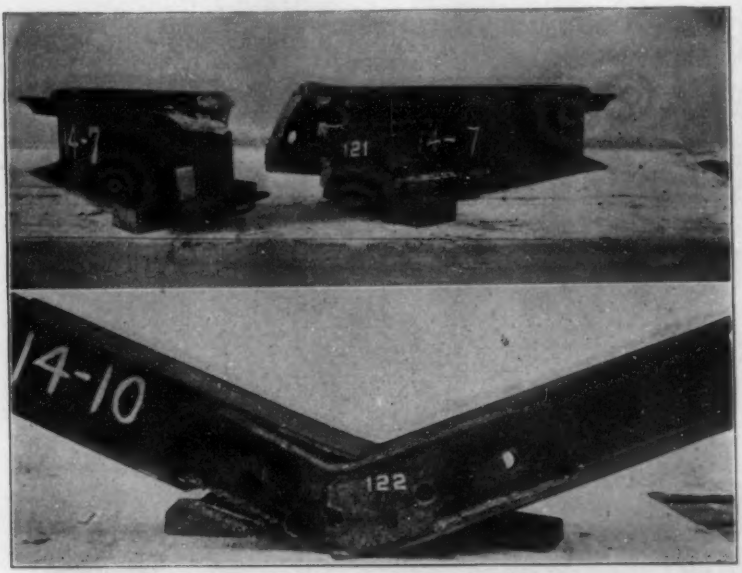


Fig. 37 — Upper two joints are seam welded specimens made by the Rail Welding and Bonding Co. under the supervision of Mr. R. B. Fehr.

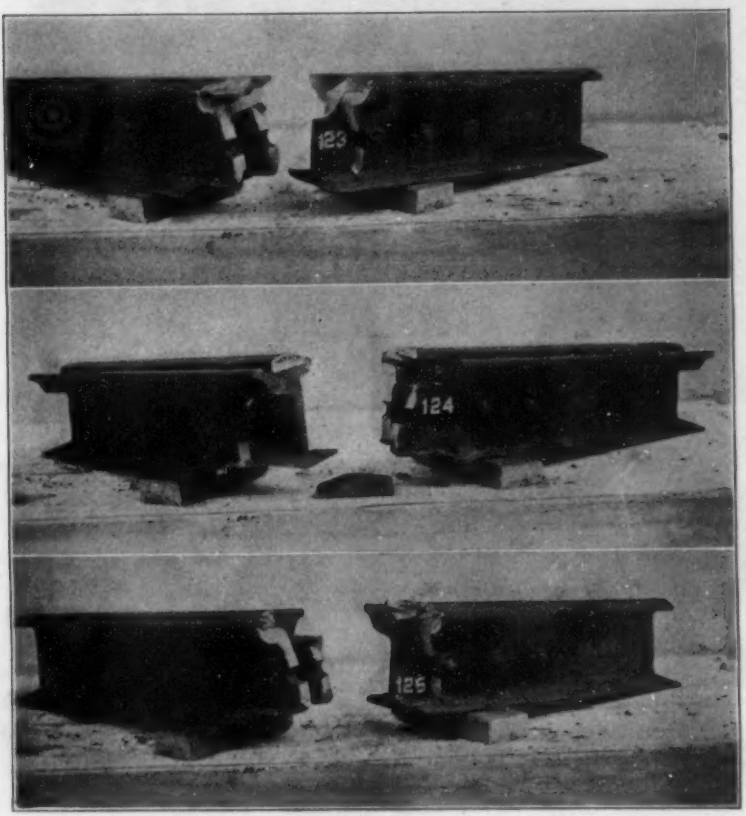


Fig. 38 — Lower three joints are the "shoulder" type of seam welded specimens made by the Third Avenue Railway System under the supervision of Mr E. M. T. Ryder.

Unbroken Rail:

Unbroken rail (marked W) broke in three places after fifteenth blow.
Unbroken rail (marked X) broke in three places after thirteenth blow.
Unbroken rail (marked Y) broke one foot from end after eleventh blow.
Unbroken rail (marked Z) broke in three places after thirteenth blow.

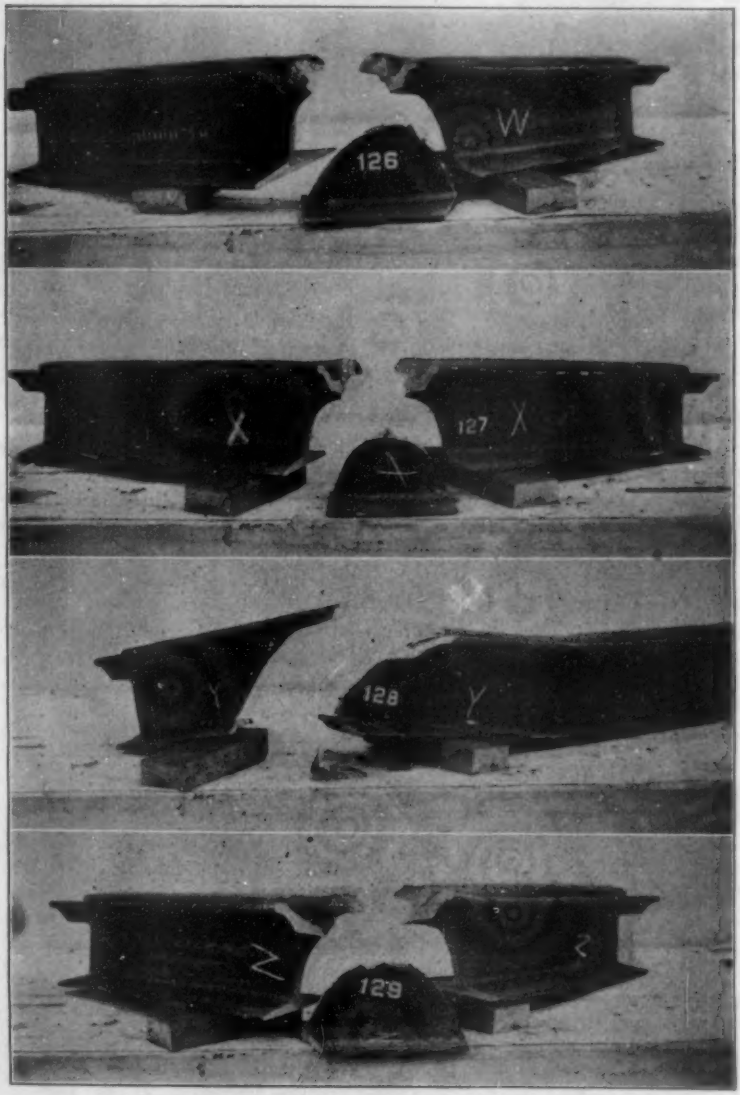


Fig. 39 — Above specimens are pieces of solid rail broken by the drop test

REPORT OF THE BUREAU OF STANDARDS ON THE REPEATED IMPACT TESTS

The Committee on Welded Rail Joints decided to make tensile, bend, and drop tests on the specimens.

If the rails are welded during the summer so as to give a continuous rail for a considerable distance tensile stresses may be caused in the rails and the joints by the drop in temperature which occurs in winter. The tensile test shows the resistance which the joints offer to these temperature stresses.

If the joints are not supported throughout their length the wheel loads cause bending stresses and the bending tests show the strength of the joints under these loads.

On the contrary drop tests made with the Master Car Builders' Drop Test Machine do not even approximate conditions which occur in service but they do measure the resistance which rail joints offer to severe bending stresses. As the rails were permanently deformed by each blow of the hammer the deflection before failure occurred was a good measure of the ductility of the joint.

It is generally believed that failure of welded rail joints in service is caused by the impact of the car wheels in passing over the joint. If there is no difference in the elevation of the heads of the rails at the joint and they are held in position so that no displacement occurs under the wheel loads, there is no impact due to the wheels.

If, however, the head of the "receiving rail" is lower than the other rail or if it is worn hollow or "cupped" by traffic each passing wheel drops onto the receiving rail and the energy of the blow depends upon the weight of the wheel and axle, the weight of the car with its load and also upon the difference in elevation of the rails.

It has been found in practice that the receiving rail often becomes cupped and the depression is usually about 2 in. from the joint between the rails and the impact which results may cause failure of the joint.

To test the joint specimen so as to simulate service conditions the Committee decided to use a repeated impact test.

Mr. E. J. McIlraith designed a machine for this test in which a hammer was lifted by means of a cam and dropped repeatedly on the joint to be tested. The design attracted the attention of many street railway engineers and the test was considered very valuable in judging the life of the joint in service. A repeated impact test was recommended on Sept. 30, 1922, by the Bureau of Standards in its report "Methods of Testing Welded Rail Joints for the Committee on Welded Rail Joints."

In order to measure the energy of the blow in service Mr. McIlraith placed lead inserts in the head of the rail and measured the amount of depression after a wheel had passed over them, then found experimentally the height from which a car wheel must be dropped to cause the same depression in similar lead inserts. These are, it is believed, the only measurements of wheel impact in street railway service. He found that the energy was about 200 ft. lb. if the drop was ⅛ in. and the car weighed 47,500 lb. If the drop was 1/16 in. the energy was 150 ft. lb. Use of his repeated impact machine showed that 4,000 blows having an energy of 150 ft. lb. caused cracks in the seam of seam-welded rail joints. The value, 200 ft. lb. representing very severe service, was therefore, adopted by the Committee and it was decided that the hammer should weigh 400 lb. and drop 6 in. onto the joint to give this energy to the blow.

Mr. McIlraith was made the chairman of a Sub-Committee to design the repeated impact machine. The first design was submitted in October 1922 and the final design was discussed and approved by the Committee at the meeting in Cleveland, May 21, 1923. Funds were voted by the Committee for building the machine which was constructed by the Whiting Corporation, Harvey, Ill. (for $995.00), and delivered in

October, 1923, at the Bureau of Standards where the tests were to be made. The Bureau offered to provide laboratory space for the machine and part of the time of one materials engineer to operate it. A 2-horse-power 500-volt electric motor was donated by Mr. G. Estill of the New Orleans Public Service, Inc., and Mr.

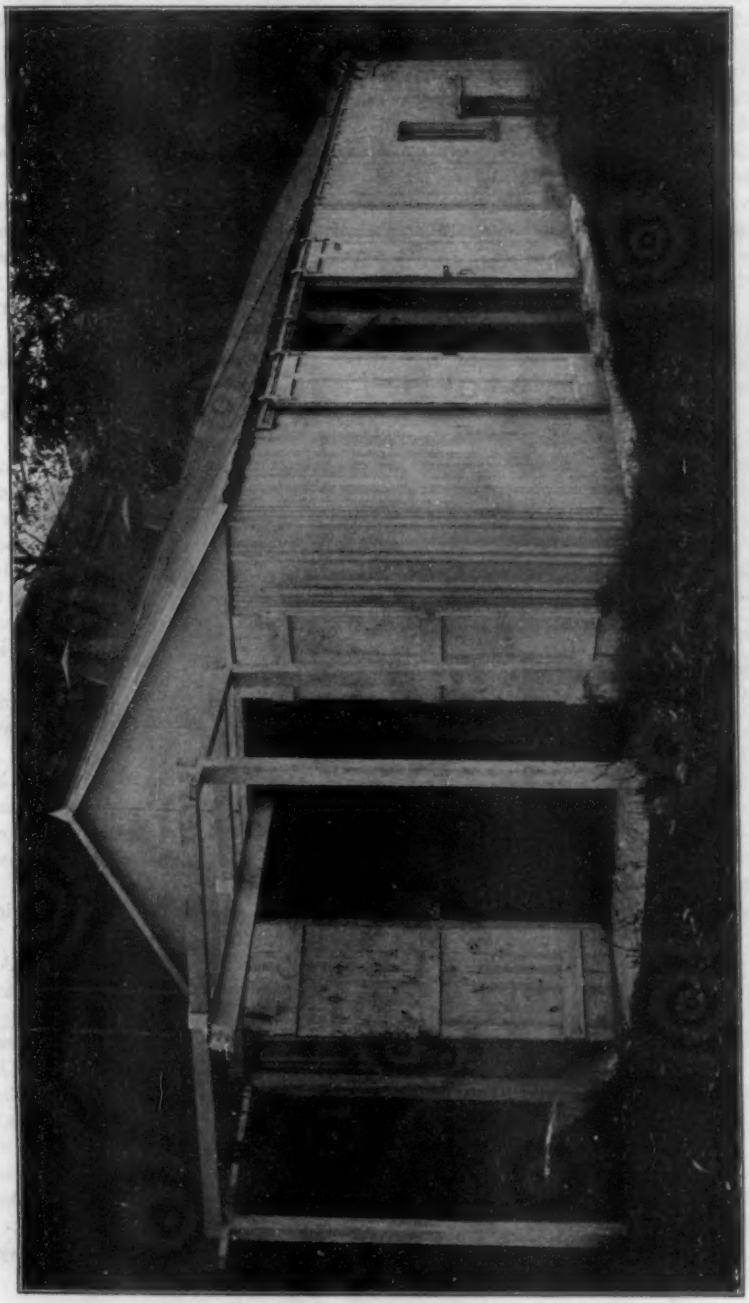


Fig. 40 — Housing for repeated impact machine.

Dalgleish of the Capital Traction Co., Washington arranged to have the Company's lines on Connecticut Ave. connected up with the Bureau and so supply current gratis.

As it was feared that the noise from this machine would be disturbing if it was operated in any of the existing laboratories the Bureau of Standards built a small one-story laboratory to house the repeated impact machine and the test specimens. A one ton chain hoist suspended from a trolley running the full length of the building was provided for use in installing the machine and moving the joints.

At Mr. Spraragen's suggestion means were provided for blocking up the frame of the impact machine to bring the hammer to any desired height. The hammer was provided with an insert on its lower surface where it came in contact with the rail. The undersurface of the hardened tool steel insert was shaped like the corresponding undersurface of a car wheel.

When the method of supporting the rail joints in the impact machine was discussed great differences of opinion were expressed. Many of the members of the Committee wished to approximate service conditions by supporting the rail joint on two ties held in place by ballast. Others preferred a rigid continuous support such as a heavy I-beam on which the rail to be tested should be supported for its entire length.

The Bureau of Standards emphasized the necessity of supporting the joint as a beam struck at the middle on an anvil which should be very heavy compared with the hammer. An anvil weighing 40 times the weight of the hammer was suggested and computations by a member of the Bureau staff showed that in all probability an anvil of this weight would be satisfactory.

In investigational work it is necessary to make tests under conditions which can be reproduced by other experimenters. If repeated impact tests of welded rail joints are ever undertaken elsewhere, the conditions so far as the machine is concerned would be the same if the weight of the hammer, the height of drop and the number of blows per minute were the same as in the tests made by the Committee. The number of blows required to cause fracture will depend upon the method of supporting the joint and will in general vary from one machine to another. The easiest way to obtain supports which can be duplicated is to use a heavy anvil, which in turn rests on springs.

A spring supported anvil has been found necessary for other impact tests as for example, the Master Car Builders Drop Test Machine, if the results from two machines are to be compared.

Although no attempt has been made to test joints supported on wood ties or in other ways which are used in service, experience with the machine leads to the conclusion that it would be practically impossible to keep the joint in the proper position under the 400-lb. hammer and that the ballast or other support would become displaced causing the height of drop to vary greatly.

It must be remembered that it is much more difficult to hold a short rail joint in position with ballast than to hold two continuous rails in place for a track.

After many discussions the Committee decided to use an anvil and Mr. H. F. A. Kleinschmidt, Lorain Steel Co., was made the chairman of a Sub-Committee to design the anvil, which was to weigh 16,000 lbs.

As the impact machine was nearing completion every effort was made to hasten the work on the anvil. The first design was submitted to the Committee on Nov. 13, 1923, and the final design Drawing 103481 — on January 9, 1924. In the meantime the other members of the Committee had made many suggestions for supporting the rail specimen as beams and holding them in place on the anvil.

Mr. Ryder suggested bolting 30 ft. rails to each end of the joint specimen. These rails would, he believed, make the test approximate service conditions, and make the results very much more valuable.

Mr. R. H. Pinckley wished to have high tensile stresses in the rails while they were undergoing the repeated impact test.

When it was found that the cast iron anvil could not be built for less than $1,400.00, the Committee considered the possibility of using a lighter cast iron anvil or if possible a concrete anvil. The latter suggestion was abandoned as it seemed unlikely that a concrete anvil would resist the blows of the hammer for any length of time. The situation was finally met by the purchase of the 16,000 lb. anvil by the Bureau of Standards. The anvil was made by the Federal Shipbuilding Co., and delivered about July 1, 1924.

While operating the machine for the first time on July 17, 1924, the cam broke. The design and construction of new cams and the replacement and reinforcement of certain other parts of the machine delayed the program at first, but for the greater part of the time since its installation the impact machine has been in operation daily under the supervision of a member of the Bureau staff. Since December 1, 1924, the machine has also been operated at night from 4:30 P. M. to 2:30 A. M. by an operator paid by the Committee.

Fig. 41 — Welded rail joint specimens to "determine present state of the art."

Bureau of Standards Report—Repeated Impact Tests:

Failure of Original Cam:

After a few minutes of operation of the repeated impact testing machine the bronze cam received several blows of the hammer while the speed was being adjusted. Because the speed was so great the hammer, upon being released at top of its travel, did not have time to strike the rail before the cam started to lift it again. The cam fractured through the keyway, making a new cam necessary.

New Cam:

As these preliminary tests showed that the framework of the impact machine was, apparently, sufficiently resilient to absorb the energy when the hammer struck the cam, no changes in the framework were necessary. It was decided to design a new cam for 6 in. drop to be made of cast steel. No removable piece was provided in the cam where the hammer is released, as it was not believed that the wear

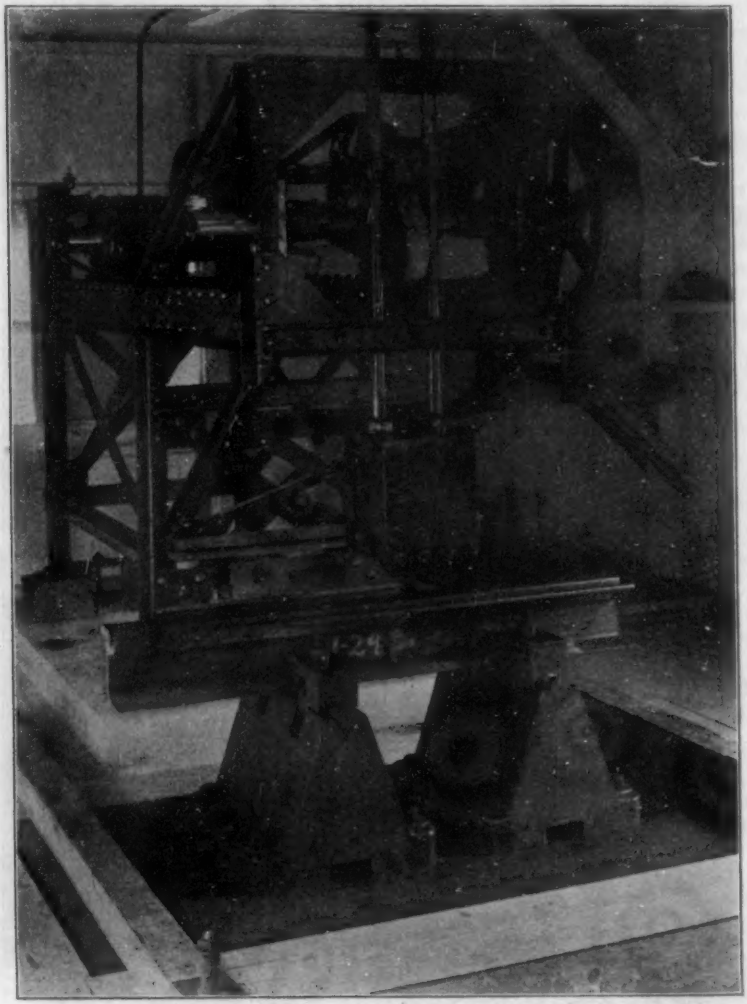


Fig. 42 — Repeated impact machine with welded joint in position for testing.

would make this necessary. It can be provided by machining a corner out of the cam and fitting in a hardened steel block.

The design of the cam provides for a uniformly accelerated motion from the point where the hammer is in contact with the rail up to mid-height and a uniformly decelerated motion for the remainder of the travel of the hammer. A

Fig. 43 — Cast iron joints made by Brooklyn-Manhattan Transit Corp'n under the supervision of Mr. R. C. Cram.

cylindrical arc of 45 degrees is provided to allow the hammer to come to rest before it is dropped.

The new cam was obtained from the Naval Gun Factory, especial attention being given to obtaining a steel sufficiently hard to withstand the abuse which it is likely to receive in service.

The contour of the cam was not machined accurately to form the casting, being merely smoothed up with a file. Care was taken to cut the keyway in the thickest portion of the hub of the cam and no failure through the keyway is expected. Lubrication has up to the present time been graphite grease applied at intervals with a stick, but automatic lubrication will be provided, if it seems desirable.

Cam Shaft:

As the cold rolled steel shaft (2 in. diameter), which was supplied with the machine, was bent by the preliminary tests, a new shaft was made from heat treated chrome nickel steel having an ultimate strength of about 125,000 lb. per sq. in. The diameter was increased to 2½ inches to secure greater strength. Like the cam, the shaft was obtained at the Naval Gun Factory.

New solid cast iron boxes having heavy flanges were made for the shaft and lined with bronze sleeves about one-quarter inch thick. These boxes were attached to the framework of the machine by drive bolts. As it was found on trial that the rebound of the hammer caused a severe blow on the cam under the best adjustment of the speed which could be made, a third cam was designed for a rebound of about 2 inches, which operated somewhat better, but the variable rebound of the hammer made it impossible to design a cam which would work satisfactorily.

Fig. 44 — Cast iron joints made by Milwaukee Electric Railway and Light Company under the supervision of Mr. R. H. Pinkley.

Wedge Device:

Three or four devices were, therefore, made for catching the hammer at the highest point of the rebound and supporting it until the cam lifted it again. Because of the severe abuse which these mechanisms received, failures were frequent and it was necessary to operate the machine slowly (about 45 blows per minute).

The more recent devices are quite substantial and can be used with good results, if they become necessary. With the friction brakes on the anvil, which are described later, it has been found that the speed of the motor can be adjusted to secure satisfactory operation when testing the cast iron welds, and probably for other types of joints.

Supports for the Joints:

An unwelded piece of rail was placed in the machine on a span of 36 inches and the machine operated by hand so as to drop the hammer from a height of 6

inches onto the rail at the middle of the span. It was found that there was sufficient resistance in the rail to cause the hammer to rebound to a height of about 4 inches. The span was shortened when it was found that the rebound was much less. After considerable discussion it was decided to use a span of 22 inches, which was the shortest practicable span for the cast iron joints. This span can be used for the seam welded joints having no base plates by making special clamps to hold the rail to the supports. This has been done by machining straps of steel about 2 inches thick, 6 inches wide and 24 inches long, so as to fit the head of the rail. A long bolt, one end of which fits the slot in the top of the anvil, passes through each end of the strap so that the rail can be held securely to the supports.

For the seam welded joints having base plates it will be necessary to cut the plates to the width of the base of the rail for a distance of about 2 inches at each end. It is believed that this can be done satisfactorily by an oxyacetylene cutting torch. Although all the type of joints have not been tried, it is believed that these supports and holding fixtures can be used for all the types. The span will, in all cases, be 22 inches and the hammer will strike the rail at the middle of the span and 2 inches from the crack between the ends of the rail which are in contact at the joint.

No attempt has been made to attach 30 foot lengths of rail to each end of the specimen, as it is believed that this will reduce the severity of the test and increase, correspondingly, the time required.

Anvil:

In the preliminary tests it was found that the 16,000 lb. anvil purchased by the Bureau of Standards vibrated vertically about ⅛ of an inch above and below the normal position. This caused the rebound of the hammer to vary as much as 100 per cent because the vibration did not cease before the next blow was struck. Although from the standpoint of the Committee this was not considered a serious matter, as the number of heavy and light blows might average, if several thousand blows were struck before the joint failed, it did greatly increase the difficulty of operating the machine, because the speed of the cam shaft which was satisfactory for a low rebound caused the hammer to fall several inches onto the cam when the rebound was high. It appeared likely that the impact machine and especially the cam with its shaft and bearings would not withstand this abuse even if made as strong as possible. It was this inability to adjust the speed to a constantly varying height of rebound that caused the failure of the original cam, although it is likely that occasionally the hammer will fall on the cam under the best conditions.

The vibrations of the anvil were studied carefully for some time and it was decided that the anvil should be brought to rest after each blow before the next blow was struck, if it were possible to do so. This was desirable in addition to simplifying the operation of the machine because from the standpoint of the Bureau the test conditions should be made constant, otherwise the results of the tests might be erratic and possibly worthless.

Friction devices were placed between the side of the anvil and the wall of the concrete pit. These consisted of wood blocks forced against the anvil by wood levers. As there was a possibility that the friction would cause the anvil to come to rest either above or below its normal position, the height of the anvil was measured with a dial micrometer after the hammer had been dropped by turning the cam shaft by hand. The variation for several drops of the hammer did not exceed 0.001 inch, which is negligible. The anvil comes to rest in about one-half second, so that the speed of the cam must exceed 100 revolutions per minute to cause variable rebound of the hammer due to vibration of the anvil.

The results obtained are as follows:

The hammer weighed 400 lb. and dropped 6 in.

Joint No.	Date of Failure	Approximate Number of Blows per Minute	Total Number of Blows to Cause Failure
18–6	Nov. 12	50	76,841
13–13	Nov. 22	50	127,540
13–8	Dec. 8	65	170,729
3–11	Dec. 10	65	75,275
13–14	Dec. 12	65	116,219
3–1	Dec. 16	75	223,399
18–2	Dec. 18	73	106,839
18–8	Dec. 19	70	64,202
3–8	Dec. 22	69	111,089
12–2	Dec. 24	76	126,687
15–18	Jan. 5, 1925	73	359,197
12–E	Jan. 12, 1925	73	310,100
15–16	Jan. 18, 1925	75	314,718
15–27	Jan. 22, 1925	70	137,230
12–4	Jan. 27, 1925	67	190,000

Description of Failure:

Definitions:

The *Impact Rail* is the rail which is struck by the hammer.

The *Non-Impact Rail* is the rail which is not struck by the hammer.

The *Joint* is the vertical plane between the ends of the rails which are in contact.

Rail 18–6:

The casting broke vertically through the joint to the bottom of the rails then along the bottom of the impact rail to the end of the casting. A portion of the casting remained attached to each rail. No loose pieces of the casting.

Rail 13–13:

The casting broke vertically through the joint to the bottom of the rails then along the rails both ways to the ends of the casting. A portion of the casting remained attached to each end of the rail. Portion of casting below rails broke off in one piece.

Rail 13–8:

Casting broke vertically through joint to top of base of impact rail. Then the fracture extended through web of impact rail nearly to end of casting. A portion of the casting remained attached to each rail. There were no loose pieces. The bottom of the casting was attached to the non-impact rail as well as a portion of the base of the impact rail.

Rail 3–11:

The non-impact rail broke without breaking the casting. There were no loose pieces. The fracture in the rail ran from a point 1½ inches from the joint at the head to diagonally to a point 9 inches from the joint at the base of the rail. The fracture ran through the hole in the web of the rail through which a pin had been placed.

Rail 13–14:

The casting cracked vertically at the joint on the lip side of the rails, but no crack was visible on the head side. The portion of the casting below the rails broke off in the plane of the base. The rails were attached to the casting, forming one piece, and the bottom of the casting was loose.

Rail 3–1:

The casting below the rail split off in the plane of the bottom of the rail. The

casting on the head side fell off. The casting on the lip side remained intact and in contact with both rails.

Rail 18–2*:*

The casting did not break. The non-impact rail broke from a line at the top about 2 inches from the joint to a line at the bottom just beyond the edge of the casting. (8½ in. from joint).

Rail 18–8*:*

The casting broke vertically at the joint from the top to the bottom of the rail, then along a horizontal plane in the base of the impact rail to that end of the casting.

Rail 3–8*:*

The casting beneath the rail broke off flush at the bottom of the rail, as one piece. The test was then discontinued. The side castings were still intact and in contact with the rails.

Rail 12–2 (*Thermit*)*:*

The impact rail broke straight across at the top under the hammer, i.e., 2 inches from joint, diagonally downward to 5 inches from joint at bottom of impact rail. A trapezoidal piece, including a portion of the base of both rails and some of the webs and the joint, which was 11½ inches long at bottom and about 3½ inches

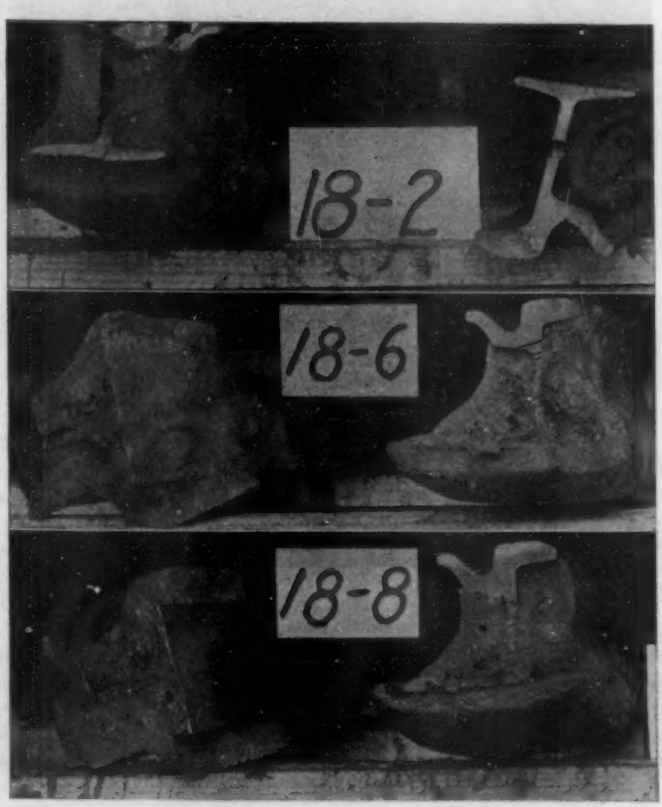


Fig. 45 — Cast iron joints made by the Minneapolis Street Railway Company under the supervision of Mr. G. L. Wilson.

high, broke from both rails. The top of this piece was horizontal, in the webs and just under the head fillets.

Rail 12-*E*:

The head of the impact rail broke across the top 4 inches from the joint, then vertically downward to 2 inches from bottom of rail, then horizontally across the joint and diagonally downward to top of base of non-impact rail at 6 inches from joint, along top of base to 9 inches from joint and then down across the base of the non-impact rail. Another crack developed in the web of the non-impact rail but did not extend quite to the top of the base of this rail.

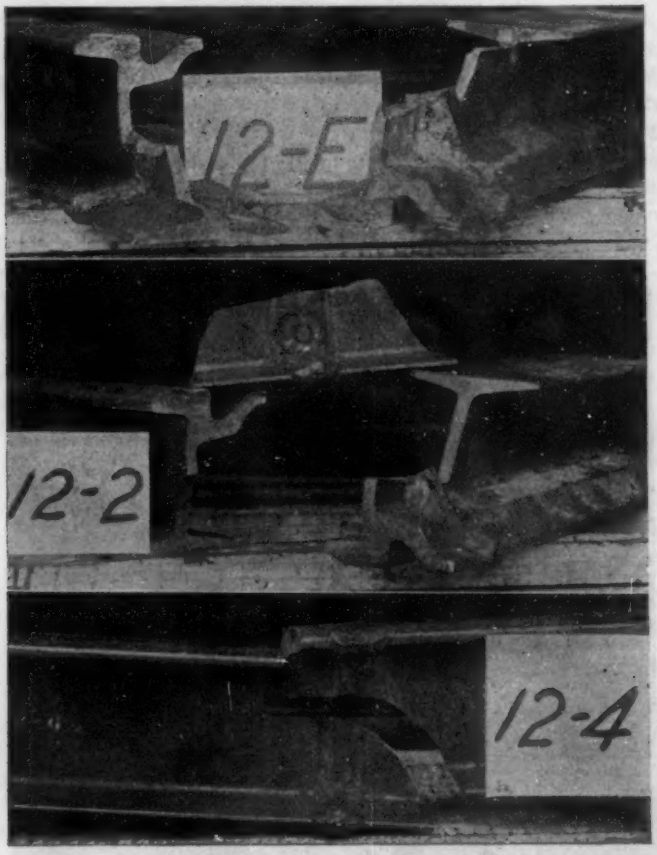


Fig. 46 — Thermit welds made by the Metal and Thermit Corporation under the supervision of Mr. J. H. Deppeler.

The horizontal crack in the web of the non-impact rail was noticed at 310,100 blows, about 20,000 blows before rupture.

Rail 12-4:

The head of the impact rail broke under the tup downward to 3¼ inches from base, then horizontally across the joint and diagonally downward to the base of the non-impact rail at 4 inches from the joint.

Rail 15-16:

The head of the impact rail broke under the tup through the head. This break spread in two directions from the fillet under the head. One developed

diagonally downward in the impact rail until, at the bottom, it was 5 inches from the joint. The other was about horizontal, crossing the joint at a height of 4 inches from the base and extending into the non-impact rail jaggedly and continuing to the base 6½ inches from the joint. The part below these cracks fell out and the joint broke under the tup. 3 pieces.

Rail 15–27*:*

The head of the impact rail broke under the tup downward to 3¼ inches from base, then horizontally across the joint, and diagonally downward to the base of the non-impact rail at 3¾ inches from the joint.

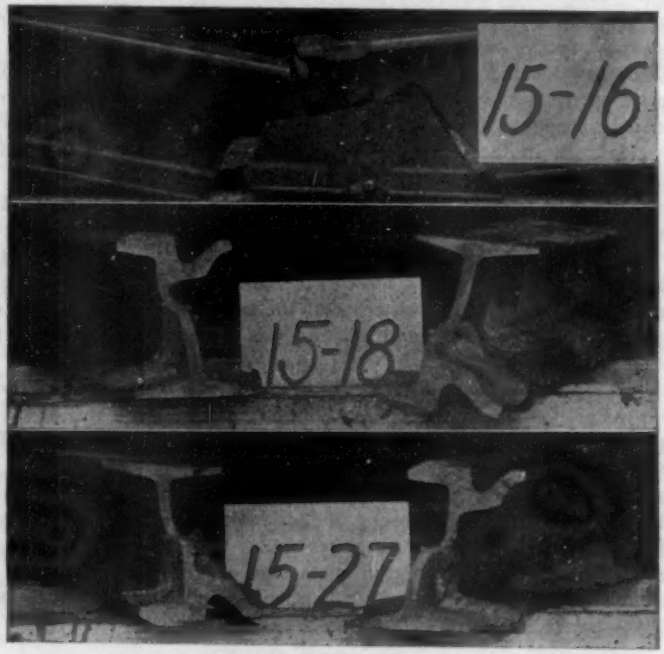


Fig. 47 — Thermit joints made by Third Avenue Railway System under the supervision of Mr. E. M. T. Ryder.

Rail 15–18 *Thermit:*

The head of the impact rail broke across the top directly under the tup, i. e., 2 inches from the joint, then vertically downward through the head to the top of the web, 4⅜ inches from bottom of rail, then about horizontally across the joint to 1½ inches from joint in web of non-impact rail, thence diagonally downward to base of non-impact rail at a line 4½ inches from joint. 2 pieces.

General description of failure for cast joints.

The failure of cast joints occurred suddenly. This might have been due to the fact that the casting covered the rails and joint and nothing of the incipient failure was visible until within a few blows of final failure. The bottom generally dropped off and very soon (perhaps a dozen blows later) the rail parted.

General description of failure for thermit joints.

The failure of the thermit joints was more gradual, at least more visibly gradual, than the failure of the cast joints. A crack appeared first in the web of the non-impact rail, turned down toward the base of the non-impact rail and

also spread across the joint in the web horizontally and then vertically in the impact rail up to a line below the striking line of the hammer (i. e., 2 inches from the joint). Since the operator is not with the machine continually, it was possible in only one case to note the manner of failure.

GENERAL STATEMENT IN REGARD TO THE RUPTURE OF WELDED RAIL JOINTS UNDER THE IMPACT TEST

S. W. MILLER

Most of the welds so far tested in the repeated impact machine were of the cast iron or thermit weld types. There was one seam weld, one bar weld and one butt weld. In all cases there was evidence of detail or fatigue fractures.

In the thermit welds the failure seems to have been first by shear through the web at approximately half way between the base and head, and this surface of shear was broken long enough before the rest of the rail gave way to be worn smooth. The butt weld broke in the same manner and shows the same evidence of detail fracture.

The bar weld broke through the joints, the plates fracturing in detail at the joint.

The cast iron welds broke diagonally from a point near the joint on the rail head to a point beyond the casting on the base. In two cases an elliptical piece broke out of the rail base. In these two cases the cast iron broke on the plane of the bottom of the base. The two pieces that broke out of the rail bases showed detail fractures at the break. In some cases the detail fracture was more clear for a short distance from one of the bolt holes.

In view of the short distance between the supports (in most cases 22 inches), I think a little calculation should be done on the effect of loading a rail of the section used at the center. I think it is probably true that under the conditions of the test, the failures were perfectly natural, although they were entirely different in type from those of the other tests. The difference between the methods of failure in different kinds of tests is very interesting and, I think, has an important bearing on design. The appearance of detailed fractures shows that the test produces stresses that are probably more than half the ultimate tensile strength. I say this because Prof. Moore has found that the endurance limit in alterating stress tests is approximately half the tensile strength.

A BRIEF HISTORY OF THE PROPOSED ROTARY MACHINE FOR TESTING RAIL JOINTS

In the autumn of 1921, or thereabouts, several Way Engineers met at a plant where joints, plates and other rail accessories are manufactured to discuss and examine the fit of joint plates, and ascertain the greatest possible area of contact between plates and rails. The discussion expanded into the field of welded rail joints and the question arose as to how joints might be tested to determine their relative merits. A rotary machine, consisting of special trucks carrying standard car wheels and operating on a circular track was suggested, and at a subsequent meeting of the Committee on Way Matters this subject was again brought up and a sub-committee appointed to study the feasibility of such a scheme and prepare a tentative design for the machine.

Shortly after the Committee on Welded Rail Joints was formed, consisting of members of the American Electric Railway Engineering Association, the American Bureau of Welding, the United States Bureau of Standards, several universities and a number of manufacturing concerns. As this Committee was formulated with the definite purpose of studying and improving various types of welded rail joints

it was decided by the Committee on Way Matters to turn over to them the consideration of proposed rotary service testing machine. The Chairman of the Sub-Committee appointed to design this machine being a member of both Committee on Way Matters and Committee on Welded Rail Joints was retained as Chairman of the new Committee to further study this subject.

A design was accordingly prepared which consisted of eight 2-wheel trucks, wheels mounted tandem fashion operating on a single rail circular track having a radius of 40 feet. The trucks were carried at the end of radial arms made of structural steel, said arms converging to a common center and revolving around a center pin carried on a substantial concrete pedestal. Trucks were connected around the outer diameter of the circle by rods so that the whole formed rather a rigid frame revolving in a horizontal plane. The frame, however, was flexible enough in a vertical direction to permit the wheels to follow any irregularities which might develop in the track. The apparatus was to be driven by two railway motors mounted on diagonally opposite trucks and each truck was to carry sufficient load of scrap iron or other suitable material to bring the total weight on wheels up to that of the average street car. In fact the trucks were so designed that this load might be varied so as to cover the range from the lightest to the heaviest of street railway cars.

Several different schemes were proposed for the support of the single rail track. One consisted of wood ties 6″ x 8″ x 4′ long spaced 2′ center to center and supported on stone ballast which in turn rested on a concrete slab, the concrete slab being carried between two vertical walls about 5′ high so that the whole machine would be about 5′ off the ground, which would permit easy inspection of rail joints even while the machine was in operation. Another scheme proposed, merely to support track on ties similar to above with ballast laid directly on the ground. This arrangement would, of course, be cheaper but the track would be harder to maintain in proper surface and alignment. Still another scheme proposed a rigid support for the track, consisting of short blocks of wood buried in the top of a concrete wall, the rail being spiked to these blocks.

The Bureau of Standards at Washington offered space on which to erect this machine and, furthermore, they offered their services in supervising the operation of this machine. In fact, it was to become a part of the equipment of the Bureau. The Committee unanimously endorsed this location although several railway companies and also manufacturers had offered sites free of charge. It was felt by the Committee that it would be very desirable to have this apparatus located at the Bureau and operated under their jurisdiction and guidance so that the results obtained would be free from any prejudice and would carry weight with the industry interested.

The design of the machine was examined by several prominent engineers and met with their approval, and final plans were drawn up and bids secured from a number of different manufacturers. All of the bids secured were surprisingly high, so much so in fact that the Committee felt they could not go ahead with this project without securing additional funds or substantial donations in the form of material. Several manufacturers did offer to supply certain materials and to eliminate altogether their profits, but even then the cost was prohibitive for the amount of funds which the Committee had to spend.

The work of designing the machine, obtaining bids, etc., involving as it did many conferences between people more or less widely separated and who were busy with other affairs, consumed a great deal of time and in the meantime some members of the Executive Committee on Welded Rail Joints felt that perhaps the same results could be accomplished by other and cheaper means. This lead to a thorough discussion in Executive session. So much opposition developed to the building of the machine even if it were possible to raise the funds that the matter was laid on the shelf for the time being.

An attempt had been made to secure the co-operation of the steam railroads but the parties who were approached on this subject felt that it was not of sufficient interest to the steam railroads and they, therefore, refused their help.

Recently, however, interest in this machine has been revived by a large manufacturer who has offered to build the machine and operate it at absolute cost, and at the last meeting of the Committee held in Washington on February 16, interest among the members was revived to some extent and it was indicated by a visitor from the steam railroads that they might become interested in this proposed rotary machine and the work of the Committee on Welded Rail Joints in general.

TELEMETER AND OTHEOGRAPH TESTS

Railway and railroad engineers have for a long time felt the need for reliable, authentic data as to the stresses in railroad and railway track caused by passing cars and locomotives and the impact blows given to joints by car wheels. A great deal of work has been done in this direction, principally under the auspices of Prof. Talbot of the University of Illinois, chairman of a Special Committee of the A.S.C.E. on "Stresses in Railroad Track." Attempts have also been made to devise recording devices to measure these stresses and impact blows.

In order to make a wide variety of studies in this field, the General Electric Company developed a device called "otheograph" which they have been using with satisfactory results. The Welded Rail Joint Committee has considered the possibility that this type might be used in its own work in measuring the blows delivered by car wheels to imperfect welded joints. A sub-committee has been appointed to take this matter up with the General Electric Company. It seems probable that both the American Railway Engineering Association and the American Electric Railway Engineering Association will be interested in these tests. A description of the otheograph extracted from an article appearing in Railway Age, Aug. 16, 1924 is included at the end of the report as Appendix B.

Electrical Telemeter

A device somewhat different from the otheograph has been developed by the Bureau of Standards for measuring and recording stresses. This instrument which is really an electrical device for recording the measurements of the strain gage has been perfected to the extent that the engineers of the Bureau of Standards

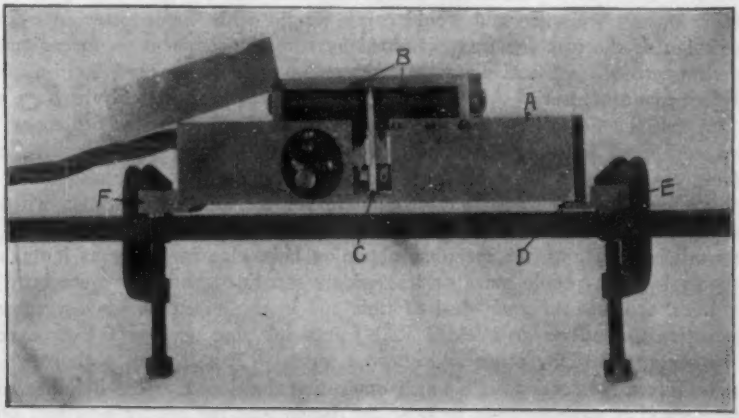


Fig. 48—Telemeter or Carbon resistor type strain gauge.

think it feasible to use in measuring the stresses caused by imperfect joints. Preliminary investigations are now being made in the street railway tracks of the local traction companies of Washington. Below is given a description of the telemeter furnished by the Bureau of Standards.

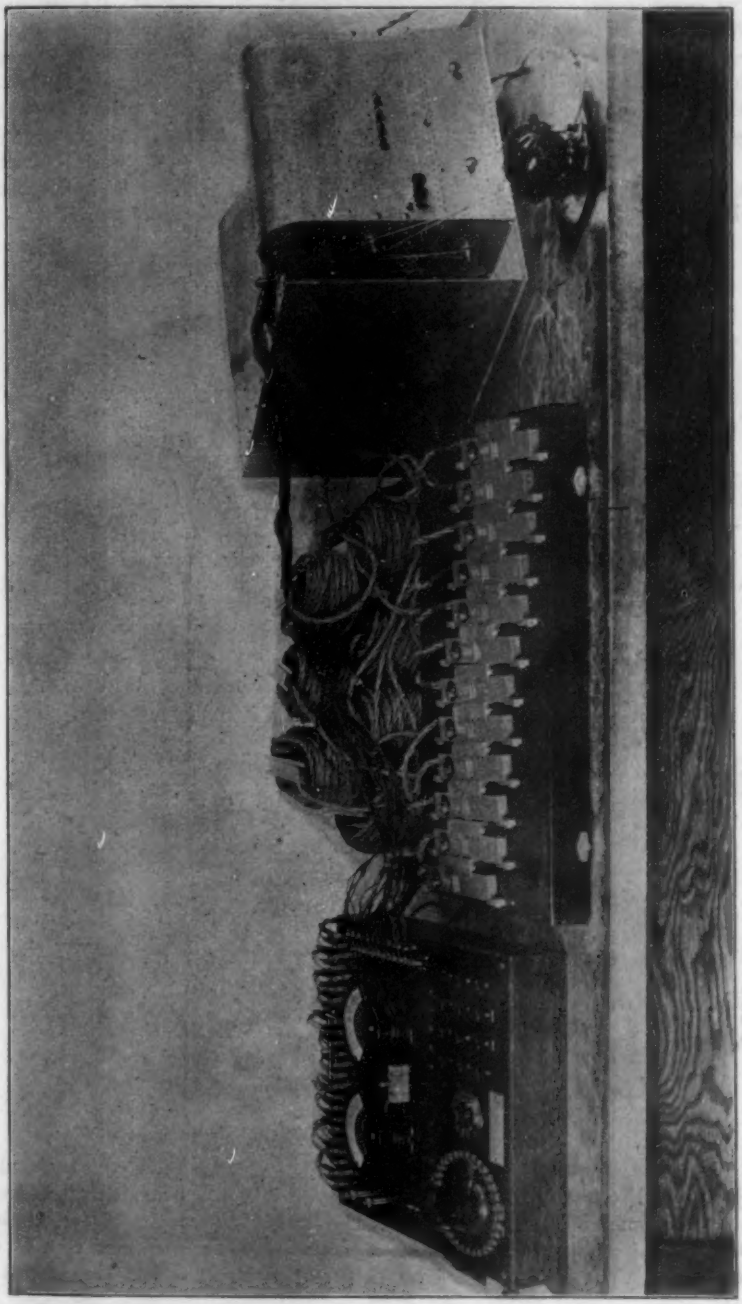


Fig. 49—Assembly view of 12-element recording telemeter for measuring strains in structural members.

The electrical telemeter is a device which may be adapted for measuring forces from any source, or for measuring strains in structural members under live or steady loads. The magnitude of the force or strain may be indicated on a milliameter if steady, or recorded photographically if of a rapidly varying character. Experiments are now being made, with good promise of success, in measuring the stresses in rails due to impact from car wheels.

An adaptation of the device for measuring strains in structural members generally, and which is being used in the rail tests, is shown in Fig. 48. This consists of a solid steel frame A with two stacks of carbon rings B mounted under pressure within it on opposite sides of a lever C which is integral with the frame. A thrust rod D passes through the frame and terminates in an anchor block E by means of which the gage is clamped to the member. The frame is provided with a similar anchor block F. The gage length may be from 2″ to 24″ or more, as desired.

Fig. 50 — Telemeter Tests
L. S. Co. 122–491 Rail Carbon arc seam welded No. 1 Standard Plates.

Fig. 51 — Telemeter Tests

A strain in the member causes blocks E and F to move relatively to each other, and this motion is communicated by the thrust rod to the lever C, which is deflected and in turn communicates the motion in reduced ratio to the stacks of carbon rings B. The electrical resistance of one stack is in this way increased, and that of the other decreased. The sum of the changes in the two stacks has been found to

be directly proportional to the strain, which makes it possible to calibrate the instrument to read directly in thousandths of an inch.

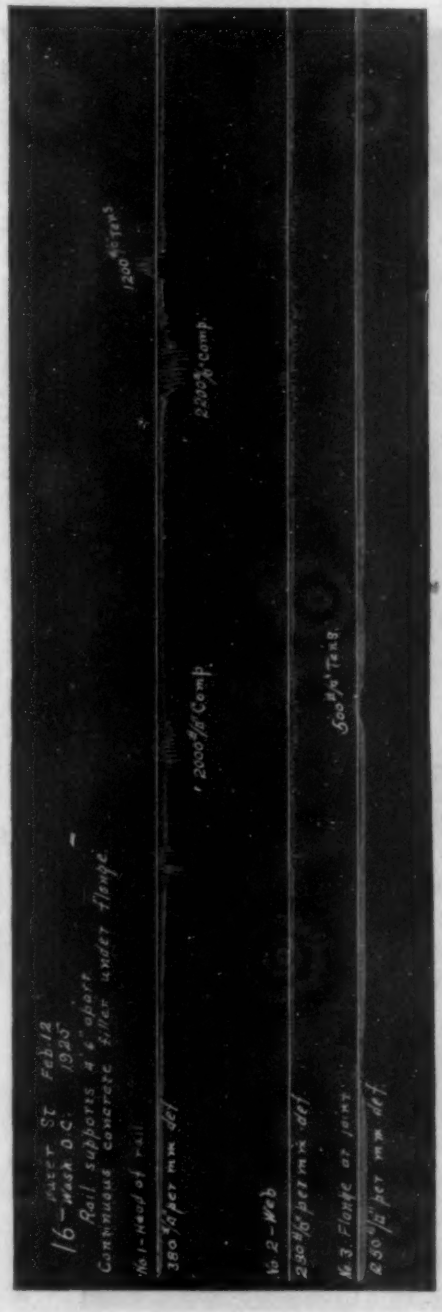


Fig. 52 — Record No. 16.

Washington, D. C., showing magnitude and character of the stress produced by the passage of a car weighing approximately 44,000 pounds. Records were taken simultaneously at three points. No. 1 on the head of the rail, No. 2 on the web and No. 3 on the flange or base of the rail at a joint 9 feet distant from Nos. 1 and 2 in the direction from which cars were approaching. Two indications were obtained at each point, one for each of the trucks of the car. The separate wheels of each truck are also indicated clearly in No. 1, less clearly in No. 3.

To utilize the change of resistance the stacks of carbon rings are made two of the arms of a Wheatstone bridge, the two other fixed arms being placed in a panel and the two parts connected together by means of a 3-conductor copper cable which may

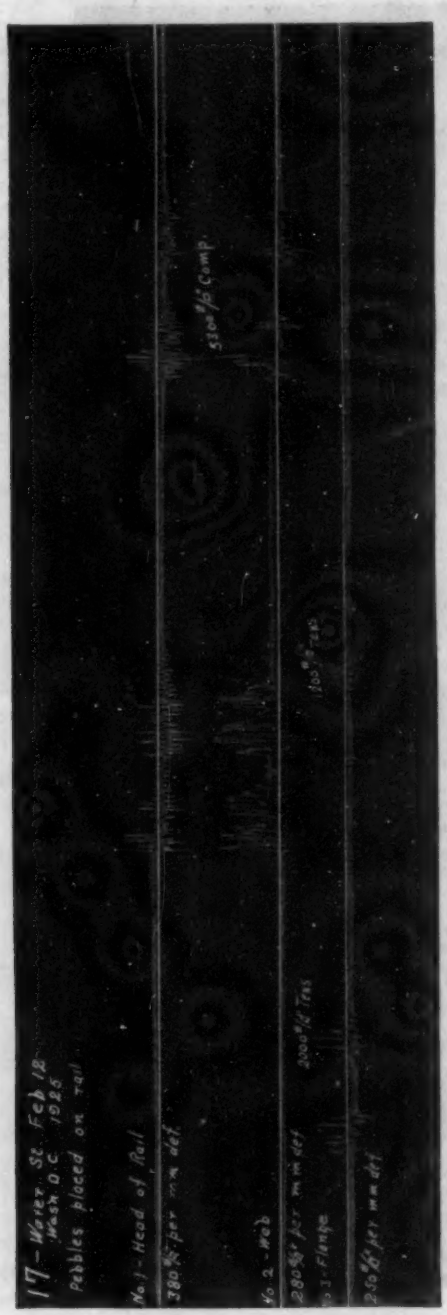

17 – Water St. Feb 18
Wash D.C. 1925
Pebbles placed on rail
No. 1 - Head of Rail
380 #/per sq in def
No. 2 - Web
280 #/per sq in def
No. 3 - Flange
230 #/per sq in def

Fig. 53.—Record No. 17.

Specimen telemeter record at the same place as for No. 16, but with pebbles approximately ¼" in diameter laid on the rail to produce an impact effect. The increase in stress due to impact is clearly indicated.

be as much as 2,500 feet long if necessary. In place of the galvanometer ordinarily used, a milliameter or oscillograph element is substituted, according to the kind of work that is being done.

The instrument is calibrated with constant current or constant voltage on the bridge circuit. Calibration is accomplished by imparting to the thrust rod D a displacement relative to the frame which is measured by means of a micrometer microscope, and reading the corresponding deflection of the needle of the milliameter, or the light spot from the oscillograph mirror. A similar deflection obtained on a test member indicates a corresponding strain, which, by means of the modulus of elasticity may be translated into terms of fiber stress in pounds per square inch of cross-section.

The instrument is capable of a wide range of sensitivity, which depends upon the proportions of the parts of the gage and the adjustment of the electrical circuits. The effects of inertia are avoided by making the natural frequency of all moving elements subject to other than forced vibration at least three times that of the phenomenon being measured, and damping such moving elements critically, or nearly so. By these means vibrations up to 550 cycles per second have been measured in true proportion by recording them on photographic film, with the record from the telemeter beside that of the mechanical vibration as a check.

The magnitude of the errors depends upon conditions, but ranges from one per cent or less for steady strains under laboratory conditions, to five to ten per cent for field conditions involving severe impact.

Fig. 54

REPORT ON CONTACT PYROMETER

At the request of the Committee on Welded Rail Joints, the Pyrometry Section of the Bureau of Standards has designed and built a contact pyrometer to determine the temperature of the rails during pre-heating and post-heating. The instrument is

very simple and can be constructed by any pyrometer manufacturer at a cost of less than one hundred dollars. It resembles a walking stick being about 30 inches long and weighing 17 ounces. Holding the pyrometer by its handle at one end, the other end is held against the rail at the point where the temperature is to be found. Wires pass through the handle and are connected to an indicator graduated in degrees Fahrenheit, so that the temperature is read directly. About 30 seconds after the pyrometer is first placed in contact with the rail, the indicator reads the temperature of the rail. This time is greatly reduced when the temperature at various points on the rail is taken in rapid succession, without allowing the tip to cool very much between readings. No training or skill is required to use the instrument and the indicated readings will probably not be in error by as much as 25° F. They should never be in error by as much as 50° F.

The contact pyrometer consists of a chromel-alumel thermo-couple mounted in a thin steel tube in such a way that the hot junction protrudes and may be placed in thermal contact with the surface of the rail. The hot junction consists of a gold disc 1 millimeter thick and 7 millimeters in diameter, into which two holes .7 millimeters in diameter and 2.6 millimeters apart are drilled partly through and No. 22 thermo-couple wire hard soldered into the holes. The gold disc is backed with mica discs to a thickness of between 2 and 3 mms to provide thermal and electrical insulation between the hot junction and the steel tubing, as well as to cushion the gold disc. The front surface of the gold disc is smooth to permit good thermal contact with the rail.

The gold tip and about four inches of the thermocouple wire form a replacable unit that can be removed by taking off a cover plate and loosening two clamping screws.

The instrument was tried out in the laboratory and was found to register a temperature consistently lower than that of the rail. The temperature registered was, of course, that of the gold disc. The meter to be used with the instrument is to be graduated to read high by the proper amount so that it will read the temperature of the rail and not that of the gold disc.

Five different units were used in the laboratory test. In four of these the thermocouple wires were imbedded in gold discs and in the fifth no gold was used, the thermocouple wires were welded directly together and flattened out into a disc. The units made with a gold disc proved far superior to the one made without the gold disc, the last one being less consistent and more sensitive to slight tilting of the pyrometer. All the readings taken with the four units making use of a gold disc fell within a range of 15° F., i. e., the highest reading with the rail at a given temperature, 950° F., was 15° above the lowest reading obtained. Unless the instrument is grossly abused, the readings should indicate with certainty the temperature of the rail within 50° F.

DATA FURNISHED BY MAKERS OF JOINTS

NOTE.—The information given below was received since publication of Progress Report No. 2.

Joints 15–29 *to* 15–42 *made by the Third Avenue Railway System under the supervision of Mr. E. M. T. Ryder.* Rail furnished by the Lorain Steel Company. Full length rails 60 feet long were laid and lined; the cuts laid out and sawed through with a hack saw; the bolt hole drilled and the plates bolted on. After the plates were all on wedges were placed in the joint at west end of rail and all were butted up tight. The wedges were inspected from time to time to see that the joints remained tight.

The analysis of the joint plates were as follows:

Carbon, .15–25; Manganese, .30–.70; Phosphorus, not over .06.

The filler rod was 9/32″ diameter, 24″ long, furnished by the Rail Welding and Bonding Company. No flux was used. Average currents for welds 225 amperes. The joints were first preheated to a temperature of about 390° F. or until a

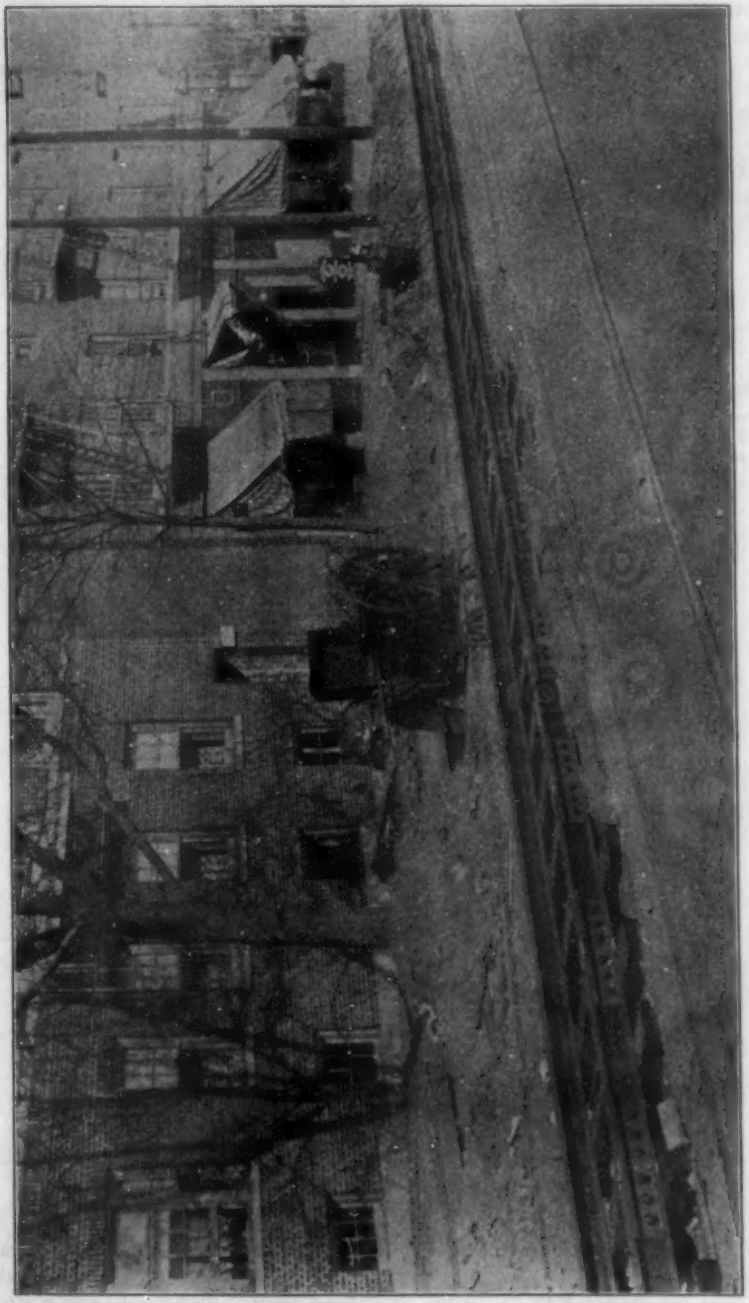


Fig. 55 — Making of the shoulder type of rail joint specimens by the Third Avenue Railway System.

piece of lead foil at the center of the plate over the joint fused, 15 to 20 minutes. The seams to be welded were then cleaned with a wire brush and the filler rod placed in position at the inside base seam. The rate of fusing of a 9/32" diameter rod was from 5" to 6" per minute. The sequence was: Inside base, outside base. Inside head, and last shoulder seam. Deflector bars were used for inside head seam. The shoulder seam was welded by placing the first filler rod in the groove next to the head of rail. The second rod was placed in the groove formed by the first rod and the place and the third was puddled down to finish. The completed joint required 3½ pounds of added metal, of which one half was in shoulder seam. The weather at the time these welds were made was variable, ranging from cloudy to fair. Temperature: 40° F. to 55° F. All bolts were tightened and sealed tight with the arc after joint was cool.

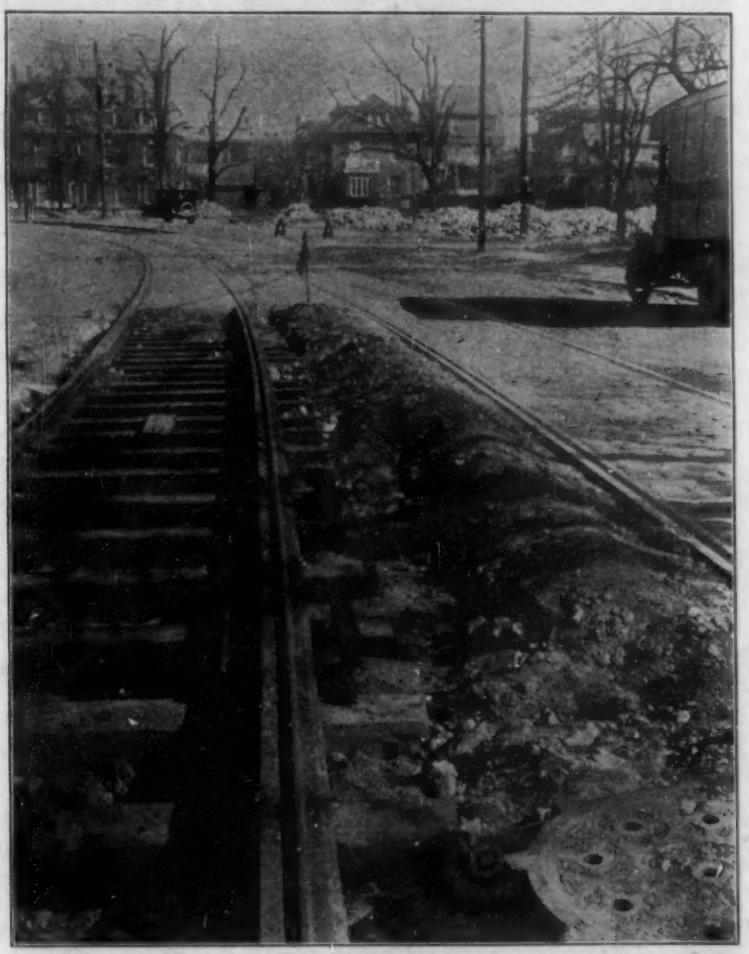


Fig 56 — Plates used in making the shoulder type of seam welded joint by the Third Avenue Railway System.

Joints were preheated by means of kerosene torch, consisting of a ten-gallon pressure tank and two torches, air pressure being maintained in the tank at about 25 pounds per square inch by means of a hand pump. One torch was placed at

one end of the plate about six inches away from it on the head side of the rail and the other torch placed at the other end of the rail on the lip side of the rail. The torches were both reversed from time to time so as to obtain as even

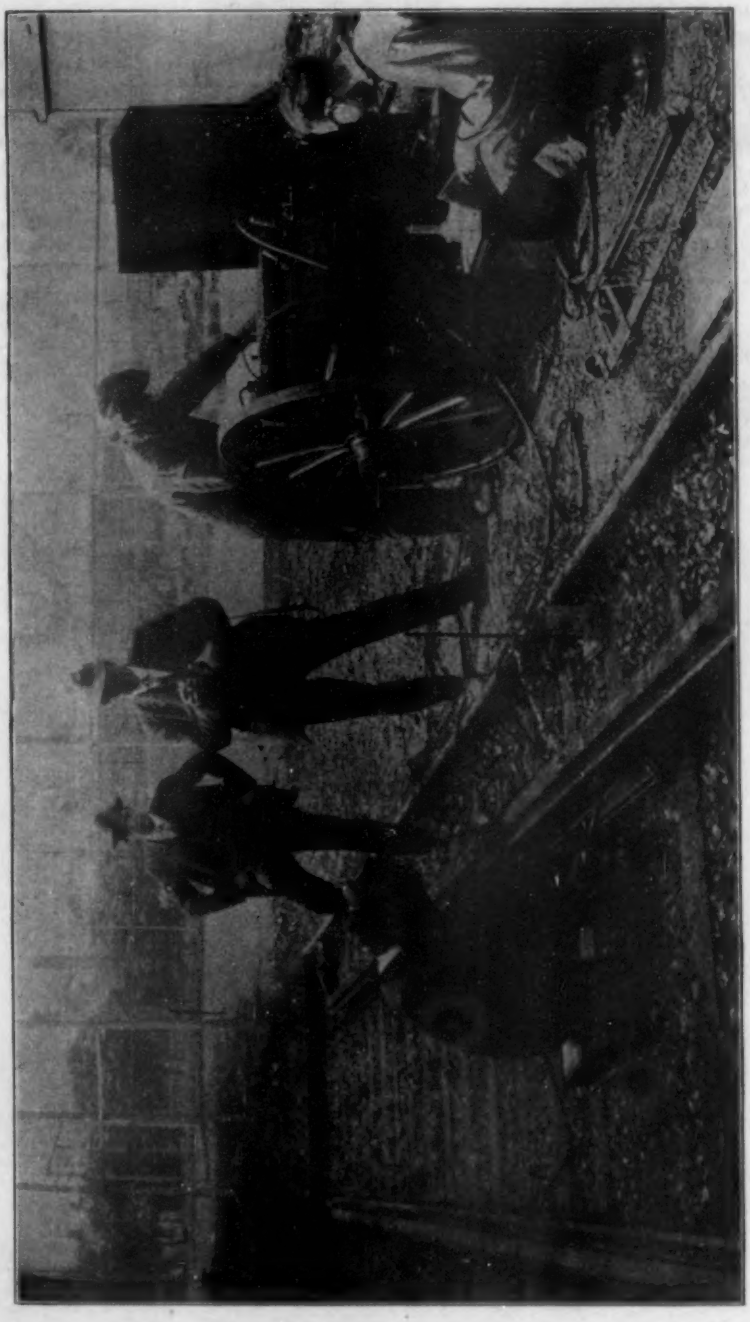


Fig. 57 — Making of joint specimens by the Rail Welding and Bonding Company.

heat as possible. Fifteen to twenty minutes, depending on weather conditions, were required to bring rail to the proper temperature. About 390° F. No Post-heating Used.

Joints 15–29 to 15–41 inclusive were cut through by a hack saw and are more accurately fitted for this reason. Joint 15–42 was slightly undercut. The rail ends being the same as cut at the steel mill.

Joints 14–1 *to* 14–14 *Made by the Rail Welding and Bonding Company under the supervision of Mr. R. B. Fehr.* The rail was furnished by the Lorain Steel Company. The fish plates were furnished by the Bethlehem Steel Company—carbon content 0.19%; manganese content 0.48%. The rails were cut in the shop to lengths of 4 ft. 6 in. and the ends were milled, square at the head and undercut slightly below the bottom of the rail head. The drift pin method was used to bring the abutting rail heads under compression. The filler rod was slowly fed in by hand on the side towards which the arc advanced.

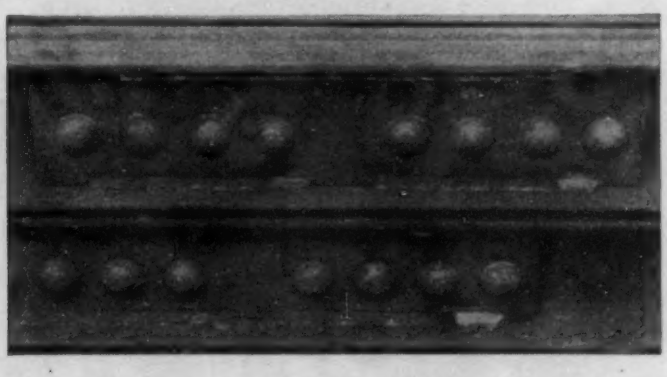


Fig. 58—Rail joint specimens prepared for the Committee by the Cleveland Railway Company.

Fig. 59—Welding specimens for the Welded Rail Joint Committee by the Cleveland Railway Company.

When the seam had been welded the arc was again applied at the beginning of the seam. Three or four inches of the seam were then retraced by a long arc so as to obtain merely surface fusion and then the second seam was welded over the remaining portion of the first seam. The final step was to postheat the double weld by the retracing operation. After each welded joint had cooled off, all bolts were removed.

A 3-inch length of the fish-plate and rail where the seam weld was to be started was preheated by means of a long carbon arc for at least 10 seconds. The temperature was thus gradually brought up to the welding point, and at the same time the adjacent portions were so well heated up that the rate of cooling of the weld metal was considerably reduced.

All seams were postheated immediately after being welded by the retracing operation which consisted in passing a long arc along the seam weld at such a rate as to cause slight surface fusion.

Sequence of welding changed for several of the joints in accordance with the guiding principle that there is a tendency for the welded joints when cold to become concave on the side on which the seams were welded first. The sequence of welding, was, therefore, determined in each case by means of a 2 ft. straight edge applied to the running surface of the joint just prior to welding. Outside temperature 58° to 78°.

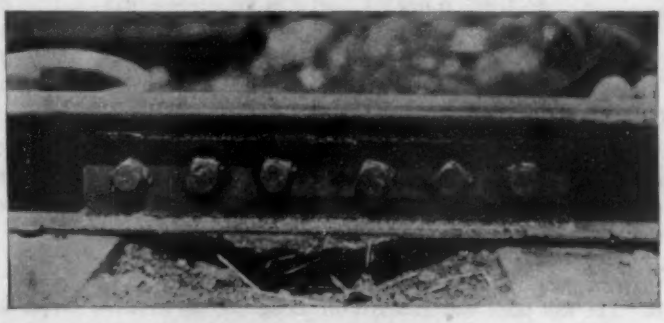


Fig. 60—View of inside plate on test joint welded and completed. Detroit Street Railways.

Fig. 61—Inside view of full length of test rail, showing test joints after welding was completed. (Detroit Street Railways.)

Joints 2–1 to 2–14 made by the Cleveland Railway Company under the supervision of Mr. C. H. Clark. Rail furnished by the Bethlehem Steel Company. Filler rods were low carbon steel. Two rods 9/32" x 10½" on top with 2–9/32" x 1" at each end on top. Two rods 9/32" x 11" on the bottom. Carbon electrodes were used, 5/16" x 12" each. Flux about 2 oz of Soda Carbonate Na_2Co_3 to each joint. The joints were welded after riveting. Forty-five minutes were consumed in welding one joint. Temperature 20° above zero. Cold and snow. No preheating. Joints were not ground. No postheating

Joints made by the Detroit Street Railways under the supervision of Mr. H. M. Gould. (Metallic Electrode Welds 7–1 to 7–12.)

Rails were laid in existing track, spiked to wood ties, and the outside ends welded to the adjacent tee rails. The joints between the test plates were fastened with standard bolted plates, with open joints for wedging so as to force the individual joints together as each is cut and welded.

	Analysis			
	Rail	*Plate*		*Welding Wire No. 9–5/32" coated electrodes*
	Heat No. 4	*Narrow (inside)*	*Wide (outside)*	
Manganese	0.830	.476	.705	1.07
Phosporous	0.028	.013	.022	0.016
Sulphur	0.075	.044	.033	0.049
Silicon	0.100	.012	.117	0.008
Carbon	0.780	.164	.352	0.323
Brinell Hardness	.....	103	131	

No flux used other than the coating of electrodes. Air temperature 34°. Sequence of welding — Welded top and bottom of inside plate first, then welded bottom and then top of outside plate. Welded nuts and bolts last. No preheating or postheating.

Joints made by the Liteweld Co., under the supervision of Mr. J. C. Lincoln. Seam Welds 25–1 to 25–12.

A base plate about 8" x 20" about ⅝" thick, was provided to place under the base of the rails. The fish plate was grooved off along the top to allow proper space for weld metal between the top of the fish plate and the rail. The weld between the top of the fish plate and the rail was made complete across the rail ends. The base of the rail and the bottom of the fish plate were welded, the weld ending about ½" or ¾" from the rail end on each side. The base of the rail was welded on the base plate, leaving the same gap at the rail ends. The weld metal was peened so as to relieve any internal contraction strains, especially on the upper seam.

PROGRAM OF INVESTIGATIONS OF WELDED RAIL JOINT COMMITTEE

Object: To improve present methods of making seam welded joints.

NOTE: Members of the Welded Rail Joint Committee voted to concentrate its efforts for the present in improving the seam welded joints. There is a greater variation in methods in use in making this type of joint than in any other. Moreover most of the street railways are using this type of joint to a more or less degree and are therefore interested in its development. Again the Committee felt that because the other types are for the most part controlled by patents that the manufacturing companies interested should make suggestions for a program of investigation.

Investigation No. 1

Object: To test several kinds of welding wire (Carbon and metal arc),—Roebling, Rail Welding and Bonding Co.'s No. 200, Armco, General Electric Company, Molybdenum and C. F. Gailor's No. 5 (carbon arc) and No. 25 (metal arc).

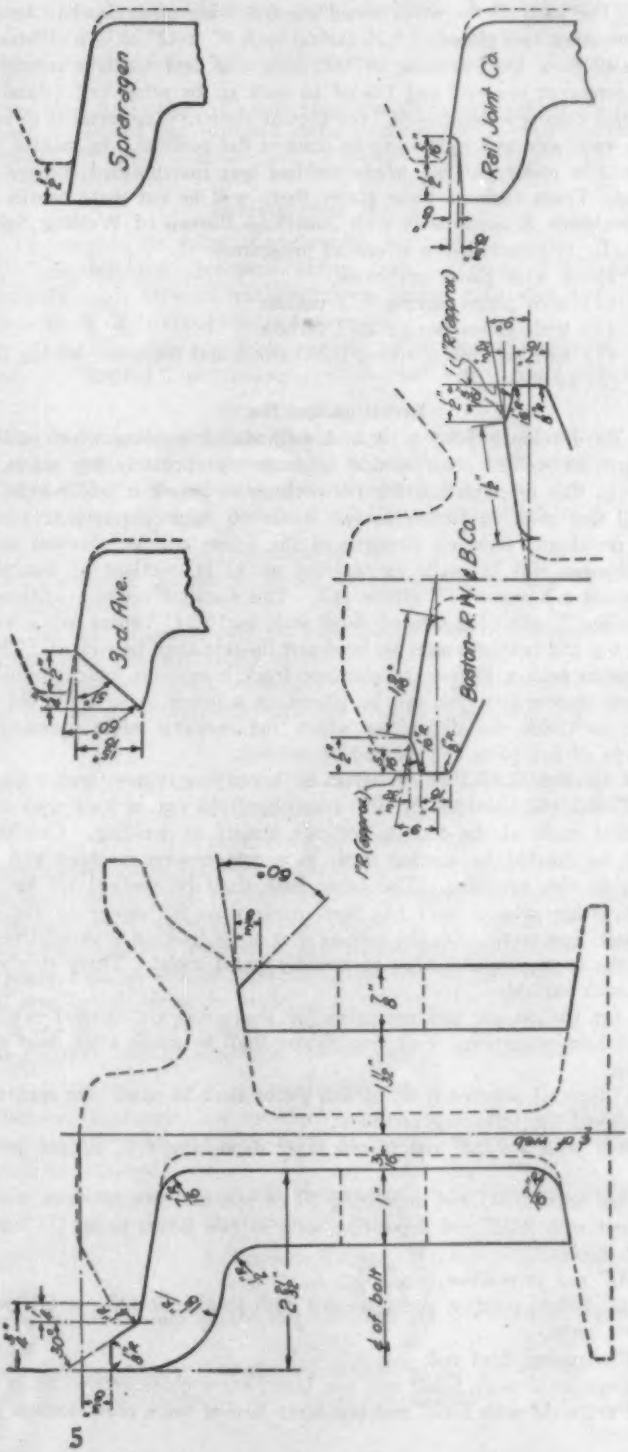


Fig. 62 — Types of joint plates to be tested by Committee.

General: For each of the wires tested the following methods shall be used:

1. Weld together two plates of 0.20 carbon each 9" x 12" x ½". Plates should be double beveled to a total opening of 90° each side and welding started with ⅛" opening at center at one end and 1/6 of an inch at the other end (usual allowance for contraction during welding — ⅛" per foot of seam). The metal is to be deposited in one layer each side and welding to be done in flat position. In making the second weld it should be started at end where welding was just finished and not started at the cold end. From each of these plates there will be cut three tensile and three bend test specimens in accordance with American Bureau of Welding Specifications Bulletin No. 1. (Extracts given at end of program.)
2. Repeat above with plates preheated.
3. Repeat (1) with plates having 0.75 carbon.
4. Repeat (2) with plates having 0.75 carbon.
5. Repeat (1) with one plate having 0.20 carbon and the other having .75 carbon.
6. Repeat (2) as above.

Investigation No. 2

Object: To develop a joint plate and methods of welding which will give the maximum area of welded cross section in seams; particularly top seams.

General: In this investigation for the preliminary work it will not be necessary to make full size joint specimens as two kinds of values, namely area of soundly fused weld metal and shearing strength of the seams will be obtained as indicated below. Specimens will be made by welding up 12 in. sections of fish plates in a 60 ft. Association Standard 7" girder rail. The distance between sections shall be at least 3". The length of a welded seam shall be 10" (1" space being left at each end). Both top and bottom seams on head and lip side shall be welded. The welding shall be done in such a manner to simulate track conditions which means that the rail must rest on the floor and not be placed on a bench as it is the object in this investigation to check the difficulties which the operator must encounter with a particular type of fish plate and method of welding.

These test specimens shall be cut apart by an oxy-acetylene torch. Each section having a 12" fish plate welded by 10" seams shall be cut in half with a saw and an examination made of the face to indicate quality of welding. One-half of the section shall be sheared by placing them in a compression machine and the force necessary to do this recorded. The other half shall be wedged off by means of a triangular wedge after a kerf has been made thru the center of the fish plate by an oxy-acetylene torch. On the section that is wedged off a careful record shall be made of the cross sectional area of soundly fused metal. Three specimens shall be made of each variable.

One wire for carbon arc and one wire for the metal arc method shall be used throughout this investigation. Full size photos shall be made after deep etching of each specimen.

Variables: Several selected types of fish plates shall be used. On each type there shall be employed the following methods:

a. Hand feed with a 9/32" rod in one layer depositing 1½" of rod per inch of seam.

b. Hand feed with 9/32" rod depositing 3" of rod per inch of seam.

c. Hand feed with 9/32" rod depositing weld in two layers using 1½" of rod per inch for each layer.

d. One 9/32" rod in position.

e. One 9/32" rod in position and rewelded with another 9/32" rod laid in position on top of first weld.

f. Repeat "e" using third rod.

g. Metallic arc weld with 5/32" rod one layer, same cross section as in "a."

h. Metallic arc weld with 5/32" rod one layer having same cross section as "b."

i. Metallic arc weld with 5/32" rod metal deposited in two layers each having same cross section as "c."

j. Metallic arc welding using ¼" rod depositing same amount of metal as "b."

NOTE: The three best types of joints from the above test will be checked by full size specimens in tension and repeated impact (three each). No pressure shall be used in bringing rail heads together. 26" joint plates shall be used for check tests. The types of fish plates to be tried out are shown in Fig. 62.

Investigation No. 3

Object: To compare the value of preheating, postheating.

General: Nine full size specimens (three each for drop, tensile and repeated impact) shall be made of each variable given below with wire and joint plates selected as a result of Investigations 1 and 2.

Variables: (1) Make nine specimens without preheating or annealing, (2) Repeat 1 preheated, (3) Repeat 1 postheated, (4) Repeat 1 preheated and postheated.

Investigation No. 4

Object: To test the value of base plates. (⅜" plain plate 9" wide.)

General: Six full size specimens shall be made of each variable below with wire and joint plates selected from Investigations 1 and 2.

Variables: 1. Base plates not preheated. 2. Repeat (1) preheated.

Investigation No. 5

Object: To compare the merits of the different methods used in securing tight fit between rail heads.

General: Six full size specimens shall be made of each type with wire and joint plates selected from Investigations 1 and 2.

The following methods shall be used for securing tight fit: (1) Standard drift pin without the use of inserts, (2) with use of inserts and, (3) two pressures with use of jacks.

EXTRACTS FROM BULLETIN NO. 1, AMERICAN WELDING SOCIETY—STANDARDS FOR TESTING WELDS

1. PREPARATION OF TEST WELDS

No detailed instructions for the preparation of test welds can be given as the dimensions, material, etc., will depend upon the purpose for which the weld is being made. The test weld should, however, duplicate as nearly as practicable, the commercial welds which it represents and should preferably be of such a size as to permit preparation of enough specimens from the one test weld to make all of the mechanical tests which are to be made.

When the test weld is made with material in sheet or plate form, the longest axis of the test specimen should in general, be parallel to the direction of rolling.

2. GENERAL PROCEDURE

(a) Wherever applicable, the standard procedure of the American Society for Testing Materials as given in the A. S. T. M. Standards for 1918 (serial designation E-1-18) shall be followed.

(b) Three duplicate specimens shall be tested in any one test and the average taken as the value of the property determined by this test.

3. TENSILE TESTS,—WELD

(*A*) *Test Specimens*

The shape and dimensions of the test specimen are shown in Fig. 1 with the weld at the center.

It is especially necessary that the 1.5 inch sides of the specimens be machined, particularly if the two pieces of base metal are offset or if they form an angle at

the weld. Tests made in the latter case, where the specimens are not machined, are not reliable. Furthermore, care must be taken that specimens having the latter defects are not "straightened" before being machined because such treatment is likely to materially decrease the strength of the weld. A roughing cut in a planer or shaper which will just "clean up" the surfaces of the specimen is sufficient.

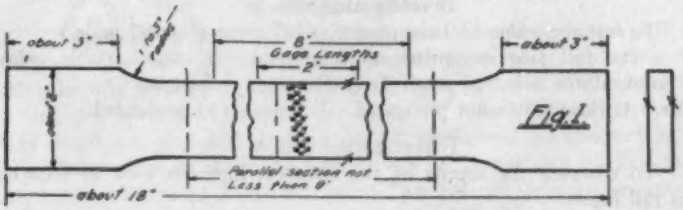
(B) Test Results to be Recorded

(a) *Ultimate Strength.* Unit stress (lb. per sq. in.) computed from the area of the original section.

(b) *Yield Point.* Unit stress (lb. per sq. in.) at which marked increase in deformation of the specimen occurs without increase of load as indicated by a sudden dropping of the beam of the testing machine or by a sudden increase of the rate of elongation as shown by dividers.

(c) *Contraction of Area.* Expressed in per cent of the original area.

(d) *Appearance of Fracture.* The appearance of the fracture as determined with the aid of a low power magnifying glass (such as jewelers use) should be recorded.



The characteristics described by the following nomenclature should be covered indicating as far as possible the per cent of the total area which is involved. For example, "10 per cent not welded" would signify that approximately 10 per cent of the total area of cross section at the fracture is exposed base metal—that is, not welded.

Spongy: Full of small cavities; the structure resembles that of a sponge; porous.

Slag inclusions: Foreign matter entrapped in the weld.

Gas pockets: Small or large cavities more or less isolated (i. e., not of a regular spongy structure).

Not welded: Exposure of any portion of the surface of the base metal indicating imperfect fusion between the base metal and the filling metal.

Laps: Imperfect fusion between adjacent portions or between successive layers of filling metal.

(The recording of the following data is optional.)

(e) *Proportionality Limit.* Unit stress (lb. per sq. in.) at which the deformation ceases to be directly proportional to the load.

Any type of extensometer may be used but in precise work the deformations of two opposite elements of the specimen, preferably on the edges, should be obtained. For ordinary purposes deformations in only one element of the specimen need be measured, but in that case the gauge marks should be on the center of the line of the 1.5" side.

The gauge length may be either 2 or 8 inches.

(f) *Modulus of Elasticity.* Unit stress (lb. per sq. in.) computed from data obtained from a specimen having an 8" gauge length; measurements to be taken on two opposite elements, one on each edge of the specimen.

(g) *Total Elongation.* Gauge marks shall be laid off every inch along a line at the center of one of the 1.5" faces of the specimen before placing in the testing machine and the total elongation in every inch after rupture recorded. The total elongation in the 1", 2" and 8" (if any) length which included the break shall be reported.

4. Bending Tests, — Weld

(A) *Test Specimens*

(a) *Weld.* The shape and dimensions of the specimen are shown in Fig. 5.

In the case of welds in flat rolled material, the surface of the weld shall be machined substantially flush with the surface of the specimen unless the specimen is bent or offset, in which case it shall be machined all over. Cast and other irregular

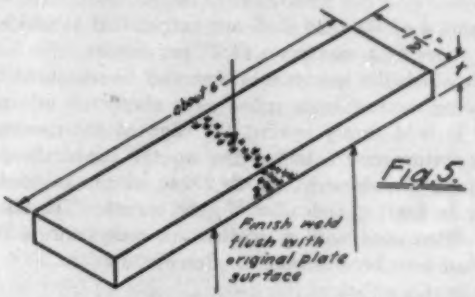


Fig. 5.

specimens shall be machined all over. It is essential that the edges of all specimens be machined to remove material in a condition likely to cause premature failure.

The thickness, t, of a weld specimen shall be as nearly that of the base metal as possible.

(B) *Apparatus*

In order to load the specimens so that as large a part of the bend as possible shall occur in the weld metal, the special fixture outlined in Fig. 6a and 6b shall be used. It is most conventiently used with any standard universal testing machine but may be operated by any other convenient mechanical means.

The cylindrical surface D, (Fig. 6a) about which the specimen is bent shall conform to the requirements of the American Society for Testing Materials for

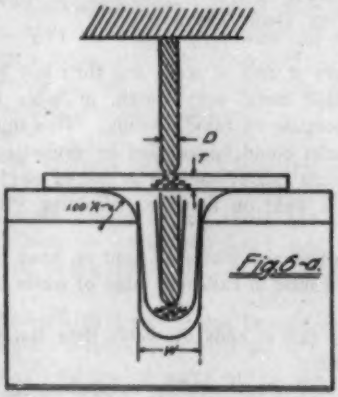


Fig. 6-a.

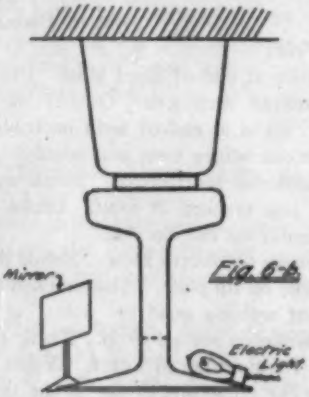


Fig. 6-b.

bending tests of the base metal.* This piece is attached to the under side of the

* For ship-plate steel (58000-68000 lb. per sq. in. tensile strength), it is "The test specimen shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material ¾" or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over ¾" to and including 1¼" in thickness, around a pin the diameter of which is equal to 1½ times the thickness of the specimen; and for material over 1¼" in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen."

moving head of the testing machine. Upon the platform shall be fastened two blocks having machined top surfaces and polished corners of radius, R, of 1.00". These blocks shall be separated by a distance, W, equal to D plus 2T plus ⅛". A lubricant of lard oil and graphite or similar compound shall be used on these surfaces.

Two specimens shall be tested. The load shall be applied at the center of the weld,—in one specimen to the open side of the "V" and in the other specimen to the closed side.

The rate of application of the load shall not exceed that at which the beam can be kept balanced at all times or a maximum of 2" per minute.

The angle through which the specimen is bent may be measured by any convenient method. The following method is described as a matter of information.

A piece of paper is held firmly against the edge of the specimen when it is in place on the testing fixture and a line drawn on the paper along a corner of the specimen, thus outlining the shape of the specimen so far as bending is concerned. A line is drawn before loading and after failure occurs. The change in the angle in the two lines as determined with a draftsman's protractor is the angle through which the specimen had been bent at failure. See Fig. 14.

(C) Tests Results to be Recorded

(a) The total angle through which the specimen has been bent when the first crack appears upon the convex surface (that is, the sum of the angles through which the two halves were bent). To be measured without removing the load.

NOTE: An electric light and mirror will assist in observing this surface as indicated in Fig. 6b.

(b) The load on the specimen at which the first crack occurs.

REPORT OF SUB-COMMITTEE ON INSPECTION OF FRACTURED JOINTS

JOINTS BROKEN BY DROP TESTS

Seam Welds

4–8 broke at end of third blow. Fracture at end of weld and thru last bolt hole. Rail shattered thru web. Quality of added metal very rough, probably not very good. Cracked at end of weld probably because of rapid cooling. This might have been cracked before tests and possibly cracks could be avoided by preheating.

4–10 broke on fourth drop. Break was thru rail at one end at end of weld. Plates on head side cracked at joint. Broke thru weld on lip side. Welding very rough and irregular on one lip side.

4–12 broke on fourth blow. Break thru rail and plates at joint on head plate also at bolt hole on lip plate. Also cracked thru base in rail near edge of outer bolt hole. Quality of welding good.

5–10 broke on second drop. Break thru rail at ends of welds thru last bolt hole in web. Plate remained intact. Welds poor.

5-11 broke on second drop. Broke thru rail where welding stopped on lip side and also on bottom at head side and ¾" at top on head side. Base of rail broken at opposite end at end of weld. Mr. S. W. Miller states it probably could be avoided by preheating. Plates not broken.

5–12 broke on seventh drop. On one end base broke 2½" from joint. Diagonal break thru web at joint. Not good fit under head. Broke thru plate at joint on head side, on lip side thru first bolt hole.

8-12 broke on fourth drop. Vertical cracks thru seams at base. Welding good except no fusion under lip part of way. Broke thru rail base at end of weld, on top at end of fusion 2½" from end of plate.

8–13 broke on first drop with break similar to 8–12 above. Structure coarser than in 8–12. Welding good.

8-14 broke on fifth drop. Broke in rail thru head and lip opposite second bolt hole probably on account of heating effect. At base broke thru rail at end of joint plate. At joint bottom welds broke and crack started at bottom plates for ¼". Good welds for top seams, excellent welds for bottom seams.

15–9 broke on twelfth drop. Sheared thru weld top and bottom lip side. Plate broke lip side thru joint. On head side weld held. The opposite end sheared thru top and bottom head side. Welds held on lip side on end.

15–8 broke on eleventh blow. Same remarks as for 15–9.

15–10 not broken on thirteenth blow. Lip side on top half length broke thru middle of weld, bottom all thru weld. On head side bottom weld broke thru middle. Top thru middle weld except 3" near rail end which was between seam welds and rails. Rail shattered badly. Mr. S. W. Miller recommends hand feed process.

16-5 (base plate joint) broke on third blow. Broke in rail at three points at end of plate welds. The other point at base under head side 1½" beyond plate weld. Weld very good. Rail broke at other end ¾" inside base plate weld on head side and 1¾" from end of weld lip side. Top of rail broke lip side at end of plate weld. Crack extending half way thru head.

16–9 Rail broke at end of plate welds, probably because chilling effect when welding stopped. Mr. S. W. Miller suggests preheating and staggering both plate and base welds.

16–11 broke on second drop. Broke thru rail at end of plate welds. Mr. S. W. Miller states that it is probably due to local chilling strains.

21-6 broke on third drop. Broke thru rail and plates thru end bolt hole at end of base plate seams and at end of plate seam under lip at top. Weld good.

21-12 broke on second drop. Rail and plate cracked at end of base plate weld lip side. Break began thru rail 1½" beyond base plate and extended diagonally thru web to head 4" from joint and vertically thru head (look at photo). Welds good.

21-14 broke on sixth drop. Broke thru plates both sides one end at end of bolt holes and at ends of weld. Broke thru rail diagonally starting 5" from joint on base and 3" from joint on top. On other end sheared thru plate welds bottom both sides. Lip and groove of rail badly broken (see photograph). Lip plates sheared on end where plates broke top and bottom.

Apex Joints

22–3 broke on sixth drop. Plates loose on both sides. Slight bending of plates. Plates stripped. Welds poor. Welded to web but not to plates.

22-2 broke on fourth drop. Weld broke loose from base on one end lip side from other base on other end head side. Practically no penetration. On head side other end broke thru weld and along web on top and loose from base on other end.

22–1 broke on fifth drop. Plates broke loose. No penetration. Welding very poor.

9–12 broke on seventh drop. Broke in rail at diagonal edge of plate and at about same angle. Weld pulled away on lip side for 4" from joint. Weld pulled away from base of rail.

9–11 broke on eighth drop. Both plates broke loose. No penetration. Design such that good fusion difficult to obtain between plates and web. Angle too steep.

9-10 broke on eighth drop. Plates loose except one on lip side. Head side loose entirely.

Cast Welds:

13–1 broke on second drop. Broke thru joint with characteristic fracture. Broke thru rail bast 1" from joint.

13–11 broke on third drop. Broke thru joint and along base. Characteristic fracture. Poured too cold. Many gas pockets.

13–9 broke on third drop. Fracture thru cast metal at joint. Good casting. Contact between casting and rail good.

18–4 broke on fourth drop. Broke thru joint. Casting broke on line of base for one half casting. Base for this part covered with dirt. Weld about 5% porous. Contact between casting and rail good except at top of web on head side. Good cast metal.

18–11 broke on fourth drop. Fracture thru cast metal. Not much separation of casting from rail. Some shrinkage cavities.

18-13 broke on third drop. Broke thru joint to bottom of base of rail and then approximately along base of rail. Shrinkage cavities 15% of area above base plate. Contact between casting and rail good.

3–14 broke on fourth drop. Broke thru rail 3" from end of casting thru hole in base and thru casting head side thru the pin in web on same end. Quality of metal good. Good contact between casting and rail.

3–5 broke on third blow. Broke thru joint above base head side and thru pin on lip side. Pin shifted extends to outside of casing one side. Characteristic failure along base. Quality of cast metal good. Contact between casting and rail good.

3–4 broke on third drop. Broke thru joint above base and then along base usual fracture. Sheared cast iron thru base holes. Broke thru pin in web. Quality of cast metal good. Good contact between rail and casting.

Thermit Joints:

15–24 broke on fifth drop. Broke thru rail at edge of thermit to top of web and diagonally thru thermit to joint. Blow hold under head at joint.

15–23 broke on second drop. Break at edge of weld thru rail. Base of rail on lip side not fused to thermit.

15–22 broke on fourth drop. Break thru rail 1" from joint. Broke in rail at edge of weld except head. Added metal good.

12-12 broke on fourth drop. Broke on side of insert and thru thermit metal nearly to bottom of base. Base broke at edge of weld. Added metal porous also slag inclusions below insert at lip. Insert one third welded on head side. Can be improved by better preheating method. Slag might be overcome by slight mold change.

12-11 broke on first drop. Broke thru rail on edge of weld.

12–10 broke on fifth drop. Break thru rail on edge of weld except at guage side of head where it was not welded to insert. Insert not welded 1½" from guage line on one side.

Bar Welds:*

6–23 broke on first drop. Broke thru bars at joint. Contact between rail and bar good. Bottom corner of plates show columnar structure. Heated to high temperature quickly and cooled quickly and setting up strains. Kleinschmidt states that this type of fracture seldom occurs in service.

6–22 broke on second drop. Break thru plates. Contact between rail and bar good. Casting under electrode badly burnt. Mr. Kleinschimdt states plates and web burned because of overheating due to loose contact. Blow hole in steel head chock casting ½" x 1". About ⅜" to ½" not welded at bottom of bars at center. This is true of all bar welded joints.

6–21 broke on third drop. Broke thru plates at joint. One third of head broke in rail.

6-13 broke on third drop. Broke thru plates at joint. Fracture of plates clean and web badly rusted.

6–4 broke on first drop. Broke thru plates at joints. Contact between rail and bar good.

* See H. F. A. Kleinshmidt's remarks at end of report, p. 135.

6–2 broke on second drop. Broke thru plates at joint. Weld badly burned in center.

Butt Joints:

11-36 broke on second drop. Broke in rail in head about 1" from joint and in rail above groove and lip and thru joint in web and base.

11–35 broke on fourth drop. Amount of upset all around 3/16". Notch due to slag of about same amount as upset. Broke outside of weld in head of rail. Piece of head broken out. Broke thru weld for rest of section. Degree of welding must be determined by miscroscope.

11–34 broke on fifth drop. Broke thru joint except above web where it broke thru rail 1" from joint.

11–24 broke on fifth drop. Break thru entire head and lip irregular 3" from joint on head and 1" from joint on lip side. Break thru web and base for rest of section thru weld. On base and web amount of welding must be determined by microscope. Amount of upset ¼".

11–23 broke on third drop. Notch due to slag about same depth as upset which was 3/16" all around. Break outside of weld in head of rail. Piece of head broken out. Broke thru weld for rest of section. Degree of welding must be determined by miscroscope.

11–22 broke on third drop. Broke thru joint except head which broke ¾" back from joint.

Tension Tests

Seam Welds:

4-1 broke thru rail at ends of weld and edge of outer bolt hole. Welds sheared from base of rail head side and top on lip side and base on lip side 3" allowing joint to separate ¼". Welds bad.

8–5 welds sheared thru center. Quality of welding good. Section of welding is considerably smaller than 8–8. (Ultimate strength 350,000 lbs.)

8-8 welds sheared thru center. Quality of welding good. Section of welding is larger than 8–5. (Ultimate tensile strength 810,000 lbs.)

16–6 broke in rail thru base on lip side at end of base plate weld. On head side 1½" back from end of base plate weld. On top broke 2½" from plate weld by shearing thru weld. Cracked thru the top lip side weld. Slight crack in top head side. No cracks in base weld.

16-8 broke in ends of plate welds under head and lip at bottom at end of base plate welds. Welds cracked under head and lip, allowing 1/16" opening.

16–12 broke thru rail at ends of all welds. Also thru end bolt hole in web. Slight vertical cracks in welds at top. Rails welded with gap at joint.

22-12 seam separated from base of rail. Plates do not fish properly.

22–11 weld broke loose from rail head side top and bottom. Broke loose from rail at base other end and from plate on top. Poor penetration.

22–7 weld pulled away from base of rail bottom and from web and plate on top seams.

Cast Joints:

18–12 broke thru joint. Blowholes above and below base.

18–5 broke thru joint. Casting porous near web.

18–1 Rail slipped in casting opening 3/16" at joint. Casting cracked on head side running into characteristic fracture at base. No slip on head side where cracked.

Thermit Joints:

12-5 broke thru rail 2" above base. For rest thru joint in thermit. Insert not welded 50%. Small spongy spot underneath insert.

12–3 broke thru thermit except part of base which broke thru rail. Insert not welded 60%. Cold shut underneath groove. Gas pocket at top of web.

15–26 broke in rail two-thirds of way up above base at edge of thermit—the rest of the way in joint thru thermit.

Butt Joints:

11-28 broke thru joint. Amount of upset all around 3/16". Broke all way thru weld with uniform structure. Degree of welding to be determined by microscope.

11–16 broke thru joint. Entire lip of rail has rougher fracture than rest of the break.

11–14 broke thru joint.

BEND TESTS

Seam Welds:

4–7 broke thru plate head side at joint. Weld broken vertically at bottom lip side.

4-9 rail broke at end of welds at three points and at base head side at end of fusion of base weld. Broke thru plate at bottom joint head side and thru weld at base lip side. Vertical cracks top lip seam in several places.

4–11 gave way thru plate on head side on bottom of joint.

5–1 broke thru base of rail entirely across starting from end of weld on head side. Lip plate broke thru inside of bolt hole shearing welds top and bottom to joints.

5–2 on head side base opened at joint ⅜". Same on lip side. Cracked thru plate of lip side thru first bolt hole. Weld opened ⅛" thru tension and shear.

5–3 broke thru base of rail at end of weld. Cracked welds at base in joint. Broke thru rail thru end of bolt hole and cracked up in head and lip.

8-9 broke thru plates about 1" from joints. Characteristic tension fracture for soft material. Weld sheared top and bottom lip side both rails. Appearance of welding good. Mr. S. W. Miller states joints can be improved by increasing section of weld.

8–10 broke thru plates. Sheared thru weld lip side on one end and head side on other both top and bottom seams. Considerable bending of plates. Quality of welding good.

8-11 sheared thru center of both welds on head side, on lip side other end. Plates broke at joint. Quality of added metal good.

15–5 sheared at seam at rail contact except 1" from end. Sheared thru middle bottom weld lip side on same side top was not welded to rail. Sheared thru weld top and bottom head side and broke at bottom by tension. Welding on bottom seams good. Poor weld on top lip side.

15–6 weld sheared on lip side top and bottom one end. Head side opposite end welds sheared to 3" from joint.

15–7 sheared thru weld top and bottom head side one end and on other end top and bottom lip side. Plates bent.

16–2 base plate welds sheared on one end and plates bent. Top head seams sheared on same end.

21-23 rail broke at end of base plate welding. Welds sheared on bottom (lip side). Rail broke diagonally on lip side half way between bolt holes.

21–11 sheared thru base plate welds both sides one end. Plates broken at end of inside base welds and thru inside bolt hole.

21–9 crack in base lip side at end of base plate weld. At other end sheared both sides thru plate weld. Rail broke at end of base plate welds. Crack extending diagonally thru lip and head to 4" from joint. Plate under head broken thru bolt hole at end of plate weld. Crack started same location lip side.

16–7 broke thru rail at end of plate welds and thru end bolt hole. Base broken at end of weld on one side and 1½" back of weld on other side.

16–4 sheared thru base plate welds both sides one end. Welding good.

Apex Joints:

22–6 welds pulled loose from base and plates both sides one end. Penetration very bad.

22–4 weld broke loose from plate and web top and from plate and base on lip side bottom. Same on head side other end.

22–5 pulled loose from base head and lip side on opposite ends. Penetration very poor.

9-9 weld pulled loose from base lip side and on head other end. Weld pulled loose partly from base and rail. Top seam sheared thru weld head side.

9-8 sheared irregularly at base one end head side and other end on lip. Weld broke at joint on both sides. Weld pulled loose partly from web and partly from plate on top side. Penetration very poor.

9–7 pulled away from base bottom plate on top one end lip side. On head side broke loose from plate on top. Sheared thru weld and broke away from base on bottom.

Cast Welds:

13-12 broke thru joint with general characteristic fracture. Some blowholes. Character of cast metal good.

13-4 broke from joint vertically half way and then diagonally towards base of rail and then horizontally to end of casting.

13–10 broke thru joint above base and then usual way at rail base. Character of cast metal good.

18-3 broke thru joint. Characteristic fracture along base. Fracture porous under base and opposite web both sides. May have been poured too cold.

18–7 broke thru joint thru casting to base of rail and then thru casting 1″ from joint. Blowholes one side of web above base.

18–10 broke thru joint with characteristic failure along base. Porous under rail base and one side of web.

3–10 broke in rail 4½″ from joint thru bolt hole in base. Sheared casting thru outer bolt hole. Character of fracture good.

3–7 broke thru joint. Casting under head 30% spongy between head and base head side. One end broke 30° diagonally starting at level of base and extending almost to main break.

3–6 casting broke 3″ outside of joint thru pin. Sheared casting thru base. Rail sheared along web just above base nearly to end of casting where base broke.

Thermit Joints:

15-21 broke at edge of weld. Lip side of base broke half inch inside from edge of weld. Three quarters of head not welded.

15-20 broke thru rail at edge of thermit. Excellent weld.

15-19 broke thru rail at edge of weld. Irregular break.

12-9 broke thru rail one edge of thermit—other edge diagonally thru thermit into rail on opposite side 1″ from joint. No evidence of defect at insert.

12–8 broke thru rail at one side of thermit up to bottom of fishing surface under groove. Three quarters of insert not welded. Slag inclusion entirely across weld under insert and along lip.

12–7 broke at edge of thermit to top of web and then diagonally to line of insert, then along face of insert two thirds of which is not welded. Blowholes under insert two thirds of its length.

Resistance Bar Welds:*

6–24 broke at joint thru center of bars and weld. Contact between rail and bar at fracture good. Usual effect of heating to high temperature on rail and bar. Welding good.

6–26 broke thru joint and thru rail head ½″ from end of joint.

6–25 broke at joint. Loose contact causing overheating in center weld. Not welded at bottom of web for about an inch on both sides.

* See H. F. A. Kleinschmidt's remarks at end of report, p. 135.

6–10 broke thru joint. Not welded on web 1¼" above base both sides. Contact set too tight towards top. Good weld.

6–8 crack on under side of lip 1" from end of rail clear thru to bottom of groove. Bar not welded on bottom to web on either side for an inch at joint. Broke thru bars. Blowhole ¼" x 1" in head support casting. Crack in center of web running up from unwelded portion. Steel head support chocks did not fit section.

Note:—This applies to all resistance bar joints.

6–6 broke thru plate under head. Other plate stretched. Crack thru lip ½" from joint. Rail broke outside edge of end weld.

Butt Joints:

11-33 broke thru joint. Upset very heavy.

11-31 Upset a little wider than usual. Fracture thru joint except lip above level of groove and small part of head.

11–32 broke thru joint to bottom of groove. Above that in rail metal ⅛ from joint.

11–21—80% of head broken outside of joint. Also 20% of lip. Rest thru joint.

11–20 broke thru joint except in head where it broke 1¼" away from joint.

11-19 broke thru joint except head which broke thru rail ¼" from joint.

TENSILE TESTS

Bar Welds:*

6–1 Bar broke thru center weld thru bars. Part of bar welded to head chock. Structure of fracture fair. Structure at center columnar.

6–11 Broke thru bars at center of weld at joint. Broke small piece of web. Structure at fracture good. Outside chock intact.

6–17 Broke thru bars at center weld at joint. Structure at fracture fair. Small blowhole at top of web between bars.

6–19 Broke thru bar at joint. Structure at center of weld somewhat columnar. Other end broke 2" from joint up thru web diagonally to joint. Small pieces of bar missing.

6–20 Broke thru bottom part of bars at joint 1½" up and then diagonally thru bar and rail to a point 1¼" from joint at outside of head. Center of weld somewhat columnar.

Butt Welds:

11–27 Broke thru center of weld as usual.

11–37 Usual fracture thru joint.

Cast Welds:

3–9 Broke thru center of joint to rail base and parallel rail base head side and lip side diagnally thru pin to three inches from joint and then parallel to base of rail.

3–12 Broke thru center of joint entirely across. Porous on head side. Full of blowholes.

13–7 Broke thru cast iron thru joint head side and 2" from joint lip side. Cast iron clean. Good casting.

Seam Welds:

2–1 Broke at end of base weld lip side and ¾" from base weld head side and ¼" from weld under head and at end of weld on lip side top. Broke 8" from joint. Welds on both sides underneath head and lip failed by shearing. Joint pulled open ⅛". Plate close to web making it difficult to obtain good weld under lip.

2–11 Top weld head side sheared 6" one end, 7" other. Plates stretched, opening at head ⅝" at base ⅜". Rail broke thru base 1¼" from end of base plate weld.

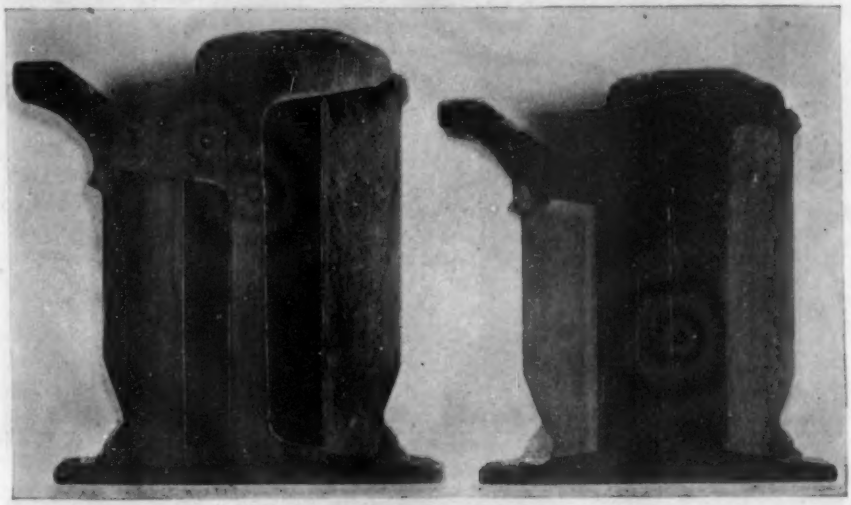
* See H. F. A. Kleinschmidt's remarks at end of report, p. 135.

Welds top on lip side not welded to plate. Bottom side not welded to base 3" each side of joint. Plate in close to web making it difficult to get weld. Arc directed so high rail simply melted down on top of plate.

2–13 Weld under head sheared 5" one side of joint 3" from other. Joint opened 5/16". Plate stretched. Base welds head side intact. Weld on top lip side probably not welded to plate. Plate close to web making it difficult to obtain good weld under lip. Rail broke thru end rivet starting at end of top head weld running diagonally to end of base weld opposite side. Joint opened ⅜" on top and ¼" on bottom.

4–2 Broke 10" from joint at end of top weld. Joint open ⅛" on rail head. Top weld head side sheared two inches from joint. Weld on lip side top sheared two inches. Not welded to base of rail 1" left hand end base seam head side.

4–3 Seam. Broke 11" from joint thru rail at ends of welds. On lip side (right hand side) weld sheared from joint 2". Bottom right end lip side two cracks in



14-4. Not etched. 14-4. Etched with ammonium persulphate.

Fig. 63 — Section sawed in half for examination.

base of rail, one 1¼" other 7" from joint extending into base 1½". Metal melted from bar making rough irregular weld. Metal melted from lip of rail same way. Joint opening ⅛".

5–5 Seam Weld. Broke 10" from joint thru rail at ends of weld on all four welds. Rail pulled apart 5/32" at center of joint.

5–6 Seam Weld. Broke thru bar lip side at bolt hole next to joint. Rail pulled apart 7/16" at joint. Weld sheared top and bottom head side one end. Sheared on lip side from break in plate to joint top and bottom.

5–7 Broke thru rail 11" from joint. Side crack going thru hole. Base of rail opposite second bolt hole broken entirely thru. Extent not visible. Joint open 1/32 of an inch. Main break in rail thru ends of all welds. Rail base weld head side right sheared from rail base break to end of weld.

8–3 Seam weld broke 10" from joint at edge of welds on base and ½" from edge of weld on top both sides. Joint opened 3/32".

9–2 Apex Joint. Welds sheared on top of bar lip side and from base same side. Weld sheared top and bottom on head side. Pulled apart 5/16".

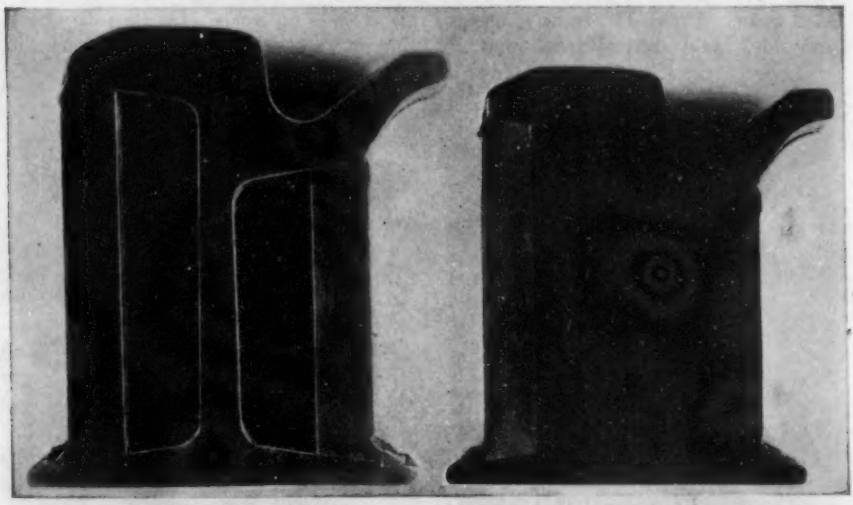
9–3 Apex Joint. Pulled apart ⅜". Weld sheared from base lipe side one end and from web and plate about half each, also top of plate lip side and thru weld at end

of plate. On head side other end weld sheared all around partly from base and partly from plate and web.

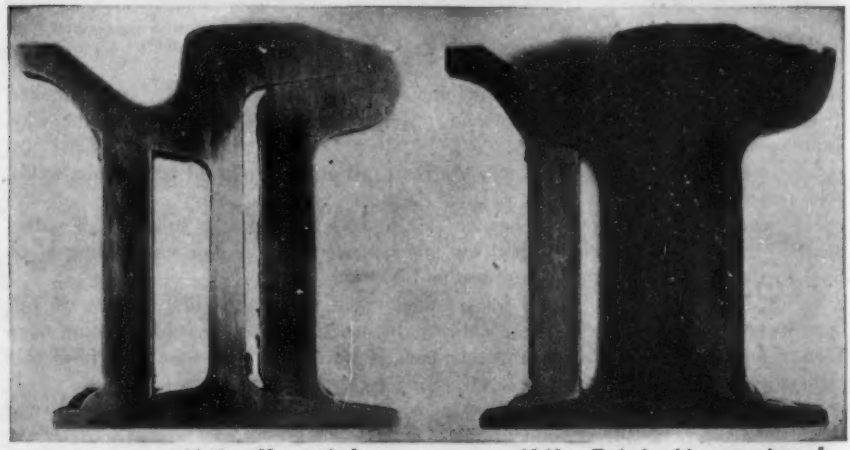
9–5 Apex Joint. Lip side base weld one end sheared 9". Rest of weld held on top lip side. Weld broke loose from web 1". Joint opened ⅜". Plate stretched. Right end bottom seam not welded to base pulled loose from web. Right end top seam showed poor fusion. Left end weld poor at base head side. Plate stretched.

14–4 Head side top weld sheared full length. Bottom weld same end sheared 1½". Joint opened ⅜". Lip side base weld sheared about ⅛", total at inside end. Plates stretched ⅛". Good welding.

Section sawed thru. Not welded at bottom of groove lip side top seam*. Width of



15-3. Not etched. 15-3. Etched with ammonium persulphate.



15-32. Not etched. 15-32. Etched with ammonium persulphate.

Fig. 64 — Sections sawed thru for examination.

* See Comment No. 2 by the Rail Welding & Bonding Company, p. 135.

deposited metal ¼" on one plate, ⅜" on lip. No welds at bottom of groove. Weld 7/16" x ½" wide head side base, lip side ⅜" x ½".

14-8 Broke thru rail base at edge of weld on lip side. Fracture extended within half of inch of welds on head side of base and on top of rail 1½" beyond welds on both sides. Welds intact. Note lab. comments.

14-11 Broke 9" from joint thru top of rail to end of bolt hole. Plate on lip side broke at joint. Rail opened 5/16". Welds on head side at base broke from rail about 2" near joint where there was indication of poor fusion to base.

15-1 Broke thru rail 10" from joint at ends of welds. Joint opened ⅛" at joint.

15-2 Head side welds sheared top and bottom one end and 3" top other end joint opened ¼". Lip side weld sheared other end top and bottom.

15-3 Lip side weld sheared top and bottom one end. 5/16" opening at joint. On head side plate stretched. Weld sheared under head about 3" from joint. Good welding.

15-3 Joint sawed thru. Head seam contact 5/16" by 7/16", min. 3/16". Lip seam 1/16", lip side 3/16" base. Head side base 3/16".

15-13 Rail broke 10" from joint at ends of welds. Lip side welds sheared top one end. Plate stretched. Head weld top sheared one end full length. Base weld head side sheared all the way.

15-29 Broke thru rail at ends of welds head side. No evidence of distress in weld.

15-32 Broke thru both bars thru inside bolt hole. All welds sheared between first bolt hole and joint, a distance of about 2½".

21-5 On lip side plate welds sheared top and bottom one end, bottom other end. On head side plate welds top and bottom sheared and base plate weld sheared. Joint opened 7/16".

21-7 With base plate. Broke 7" from joint thru end bolt holes at ends of base plate welds both sides. Rail base plate weld from end of break to end of plate sheared. Joint opened 1/16". Plate under head cracked 1/16" at top. Rail broke in head at end of top seams head and lip side. Good welds.

21-10 Rail broke 7" from joint at ends of base plate welds at top welds head and lip. Welds sheared from break out. Joint opened 1/16". Plates stretched at top.

25-2 Rail broke 14" from joint at end of base plate weld head side left end and plate weld under lip joint opened ⅛" at head. No distress in weld. Good welds.

25-5 Rail broke at end of base plate weld (right) lip side. Joint open 1/16" head-base tight. No distress on weld.

25-6 Rail broke thru 11" from joint left end. Joint did not open. Break thru end base plate weld head side and ends of both top plate welds cracked before test in base 1½" long at the end of welding.

Thermit Welds:

General note: Where in this report and those of the various laboratories it is said, referring to thermit welds, that there are no welds on the insert, it should be remembered that this is in the nature of a butt weld and fractures in the characteristic butt weld manner directly along the face of the butt weld. The butt weld between the insert and the rail head or between the rail heads themselves where no separate insert is used, should be considered in the light of a partial butt weld although imperfect at times.

12-6 Thermit broke thru center of weld at lip to web. Rest of fracture thru rail at end of collar. Collar not fused to base for ⅜". A few small blowholes. Slight slag under head at center. Piece broken out of head. Left hand side of insert not welded. Right hand side apparently welded. Line of contact faintly discernible after cleaning with nitric acid.

15-15 Broke thru one end of thermit collar thru rail.

15-17 Broke thru center of weld except 1" at end of collar base left hand side where rail broke. Two blowholes under insert.

15–25 Broke thru thermit. Base broke thru corners of rail 1¼" on each side. Rail head not welded. Slight slag underneath lip.

15–28 Broke thru center of weld except on lip side of base. Here it broke thru base at edge of weld. Large amounts of slag at bottom of flange of lip. Head not welded from top of web up — washed away. Weld metal gone at back at head. Lip in same condition. Welding badly porous. Mr. Deppeler states probably due to breaking down of mold during operation.

BUREAU OF STANDARDS REPORT ON METALLOGRAPHIC EXAMINATION OF TYPICAL WELDED RAIL JOINTS

Materials:

The welded specimens examined were selected from the tested rail joints, the examination of the fractures of which was made at the Bureau of Standards July 18 and 19, 1924. In the choice of these specimens, the characteristic features of each type of weld were given first consideration rather than the peculiar conditions in any particular specimen which may have contributed to results obtained in the testing of that joint.

Following are the specimens examined:—

Weld Number	Type
11 - 35	resistance butt
6 - 26	resistance bar
5 - 11	seam (rod in position)
15 - 22	thermit
13 - 4	cast
8 - 12, 8 - 13	seam (hand-feed system)

Electrical Resistance Butt Weld:

The specimen used was a portion of the rail head from joint 11 - 35. When this joint was tested in the drop test, the fracture occurred, for the greater part of the rail section, along the plane of the weld. In the head, however, the fracture was

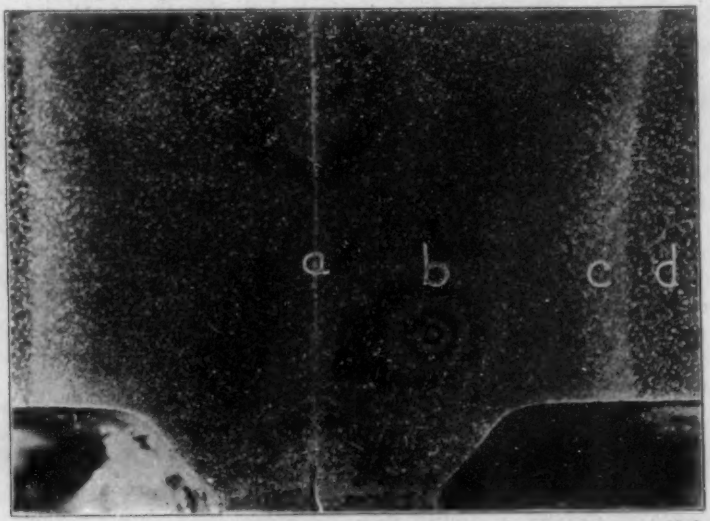


Fig. 1 — Vertical longitudinal section of the head of resistance-butt welded rail, 11–35. Note the narrow weld (central white line), the depth of penetration of the head (approximately ¾ inch here), and the relative grain size in various parts of the welding zone; etching reagent, aqueous solution of ammonium persulphate; x 2.

located on each side of the weld at a distance of approximately 1½ inches. Thus the welded part of head remained intact; this was the specimen used for examination of the features of this type of weld, a "vertical" section, as shown in Fig. 1 below being made. The principal structural features to be noted in a weld of this type are, the depth and general character of the welded layer, the depth to which the "welding heat" penetrated the metal of the rail and the changes in grain size of the metal resulting from this heating.

The micrographs following show the structure at the points indicated in Fig. 1. Etching reagent throughout 1 per cent alcoholic solution of nitric acid; magnification, x100.

One of the possible defects of this type of weld may be pointed out. This is illustrated in Fig. 1 on the lower edge (as shown on the page) of the weld. The weld was not complete to the extreme surface of the rail head but a narrow unwelded

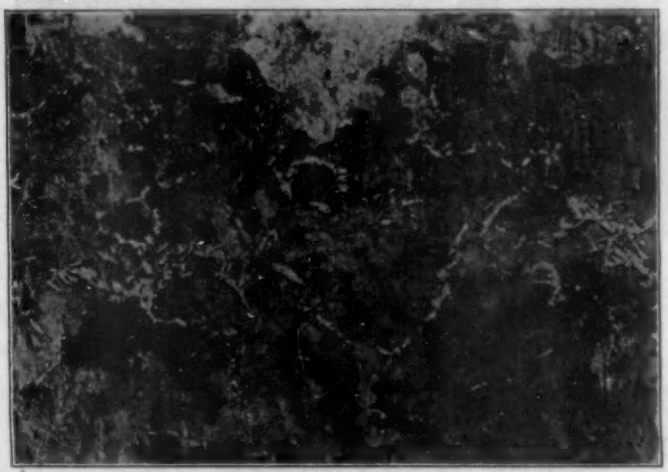


Fig. 2a — Microstructure at point "a," Fig. 1. Note the very narrow zone of welded metal. This is characteristic of this type of weld. Note also the excellent appearance of the weld in this particular specimen.

Fig. 2b — Microstructure at point "b," Fig. 1. Compare with Fig. 2d. The steel compares very favorably in grain size with the rail steel unaffected by the welding heat.

"notch" remained. Such a notch if at all pronounced might be instrumental in producing serious effects under the action of service stresses.

Electrical Resistance Bar Weld:

The specimens examined were taken from Joint 6-26. This joint, when broken by the bend test, revealed a very coarse "burnt" structure in the fracture. Two sections were examined, one a horizontal longitudinal section through the fracture and a sec-

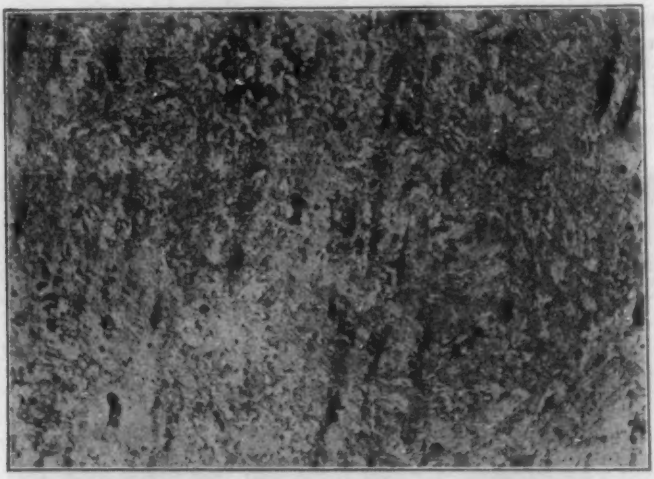


Fig. 2c — Microstructure at point "c." This point marks the limit beyond which the steel was not heated sufficiently during the welding to cause any visible structural change. Note that at point "c," a pronounced refinement of the grain was effected, this change in structure being determined by the relation of the temperature attained during the welding to the "critical range" of the steel. At this point the steel was heated just sufficiently so that the transformation occurred. The relatively rapid cooling preserved the small grain size.

Fig. 2d — Microstructure at point "d," Fig. 1. The microstructure shown here is that of the rail, that is, it shows no effect of the welding heat.

ond one, a vertical section through rail web and the adjacent welded plates at a point about 12 inches' distance from the fracture.

Fig. 3 shows the horizontal longitudinal section through the face of the fracture. x 2. Ammonium persulphate solution was used for revealing the structure.

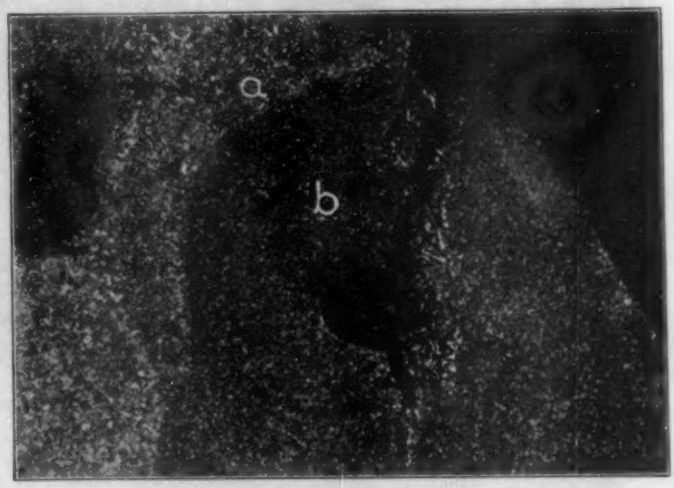


Fig. 3 — Joint 6–26. Resistance bar weld. Note the coarsely crystalline condition of the metal and the decidedly inferior character of the steel at this point. The following micrographs were taken at point "a" and "b" x 100; etching reagent, 1 per cent alcoholic nitric acid.

Fig. 3a — Microstructure at point "a," Fig. 3. Note the excessively coarse grain which resulted from the overheating of the steel during the welding.

The welding in this type of joint is done electrically. A current is passed transversely through the rail web and side plates of the assembled joint, the parts being tightly clamped at the spot where the current is passed through. Presumably the overheating shown in Fig. 3 occurred as a result of a loose contact.

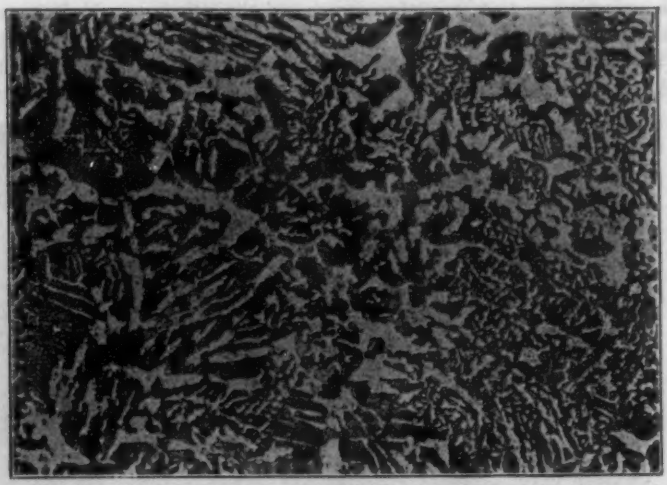


Fig. 3b — Microstructure at point "b," Fig. 3. The metal has been very severely overheated as is evidenced by the large grain size and by the characteristic "knotty" appearance of the ferrite (white constituent).

The second section cut from this joint was approximately 12 inches from the fracture. Fig 4 shows the appearance of the etched vertical section at this point, the dark central zone of the micrograph being the web of the rail and the lighter ones on the sides the plates. The effect of heating the steel plates by the application

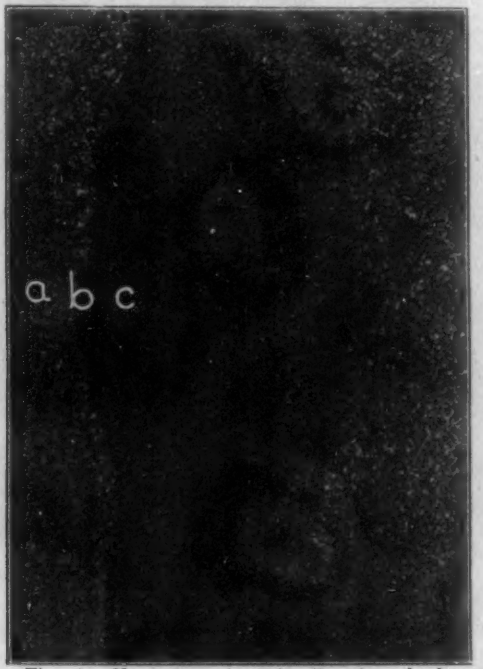
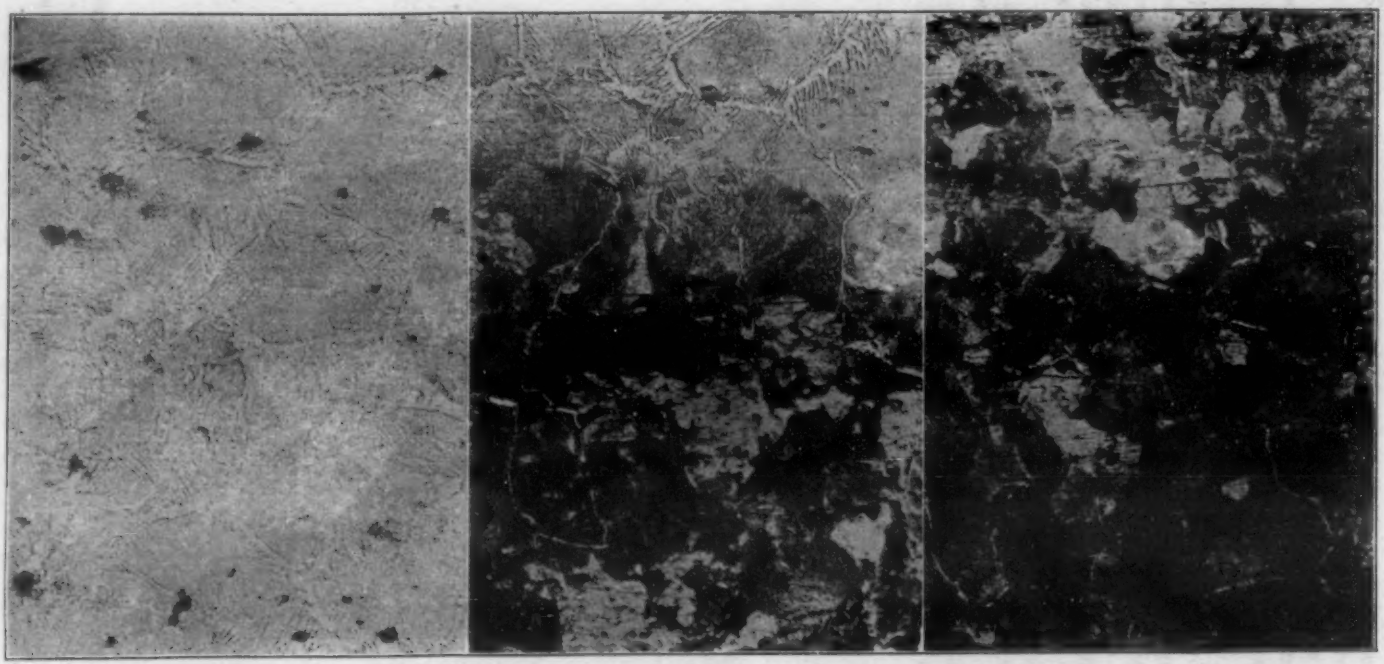


Fig. 4 — Vertical section of rail web and plates 12 inches from the fracture in joint 6–26; x 1½; etching reagent, ammonium persulphate solution. The micrographs below show the condition of the metal at "a" and "b" and "c," i.e., the junction between web and plate in a satisfactory weld of the resistance bar type.



a b c

Fig. 4a — Microstructure at points "a" and "b" and "c" of Fig. 4; x 100; etching reagent, 1 per cent alcoholic nitric acid solution. Note the intimate contact between web of the rail and the lower carbon plate in "c." The grain size has also increased somewhat in both. This is unavoidable, however, and need cause no concern if not carried to an extreme, such as is shown in Fig. 3a.

of the current is shown by the increased grain size of the metal. The structural condition shown in this macograph may be considered normal and satisfactory for this type of welding.

The pronounced weakening of the metal by overheating it is one of the possible disadvantages of this type of welding.

Seam Weld:

In the ordinary type of "seam" welded joints side plates are bolted to the rail web and welded by fusion welding along the upper and lower edges to the side of the rail head and the upper side of the rail base respectively. When joints of this kind are tested by the drop test failure in the rail base usually occurs near one end of the side plate and appears to bear some relationship to the seam weld. The specimen examined was cut from joint 5–11 from the rail base near the end of the seam where failure of the rail joint under the drop test appeared to have started.

Fig. 5 shows two different sections through the seam weld on the upper side of the rail base and shows the depth of "penetration" of the weld and the extent to which the surrounding metal was affected by the welding heat.

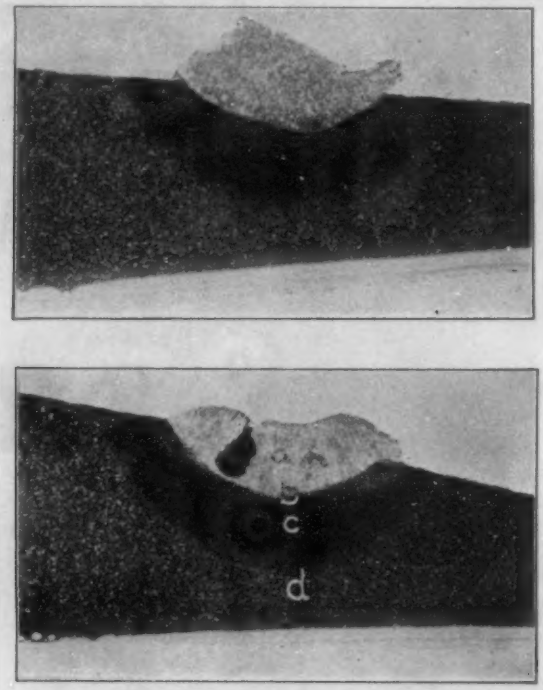


Fig. 5 — Seam weld, joint 5-11; x 2½; etching reagent, ammonium persulphate. Note the light colored "weld metal" and the dark encircling zone which marks the extent to which the adjacent rail metal was affected by the heat.

The microstructure at the points "a", "b", "c", and "d" Fig. 5 are given in the following micrographs:—

Lack of 'penetration' of the weld metal into the base and low adhesion between seam and base metal are sources of weakness in this type of welding.

b

a

Fig. 5 a b c d — Microstructure at the points indicated in Fig. 5; × 100; etching reagent, 1 per cent nitric alcoholic acid.
a. Weld metal. This is the low-carbon metal added during the fusion welding.
b. Junction between weld and base. This may be considered as typical of a very sound and intimate contact between weld and base.

d

c

Fig. 5 a b c d — Microstructure at the points indicated in Fig. 5: × 100; etching reagent, 1 per cent nitric alcoholic acid.
c. Zone of affected metal adjacent to the weld. Note (by comparison with d) how the structure of the rail steel has been refined.
d. Unaffected or initial structure of the rail base.

Thermit Weld:

The specimen examined was cut from Joint 15–22 and consisted of a horizontal longitudinal section through the "thermit" metal and the rail web.

Fig. 6 shows the polished section after etching with aqueous solution of ammonium persulphate (x2).

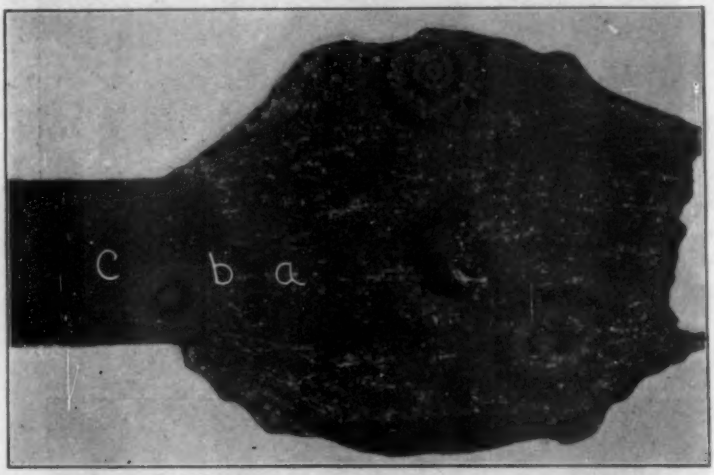


Fig. 6 — Horizontal longitudinal section through the web and added "thermit" metal of joint 15–22. Note the coarse crystalline condition of the "thermit" metal. Interior cavities and shrinkage cracks, such as seen near the center, though perhaps not to be considered as characteristic, are not infrequently found. Micrographs, x 100, were taken at the points "a," "b," and "c" indicated, 1 per cent alcoholic nitric acid used as etching reagent.

Fig. 6a — Microstructure of the cast "thermit steel," x 100. Note the very large grain size. On account of its relatively low carbon content, such metal may be expected to have considerable ductility, in spite of its other possible undesirable features.

Cast Iron "Weld":

The cast-iron rail joint depends upon several factors for its value, the character of the iron, which was all that this examination was intended to reveal, being only

Fig. 6b — Junction between "thermit" metal and rail web ("b" in Fig 6) x 100.

Fig. 6c — Microstructure of the rail web ("c" in Fig. 6) x 100. The structure was coarsened somewhat by the heat of the thermit reaction but is not to be considered as being very seriously affected.

one of them. No attempt was made to examine the "junction" between the casting and the rail as it is well known that there is no welding action here as it is other features such as the mechanical devices (insertion of steel pins before casting, etc.) that are depended upon.

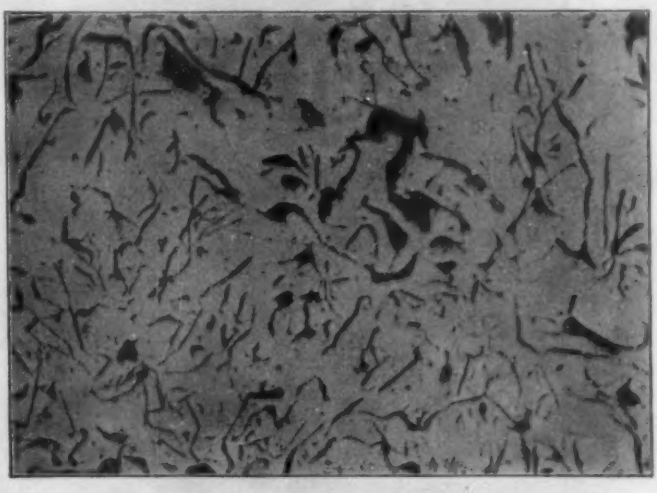
The following examinations were made of representative specimens of cast iron cut from Joint 13-4; tension test, chemical analysis, and microscopic examination.

The ultimate tensile strength of the iron as determined upon three specimens of the usual form and size (0.505 inch diameter) was 17,550, 19,950, and 20,800 pounds per square inch.

Chemical analysis indicated the following as the composition of the iron:—

	Per Cent
Carbon	3.45
Carbon graphitic	2.87
Carbon combined	0.58
Manganese	0.47
Phosphorus	0.56
Sulphur	0.083
Silicon	2.37

Representative micrographs showing the structure of the iron (x100) in the unetched and etched condition are given below:



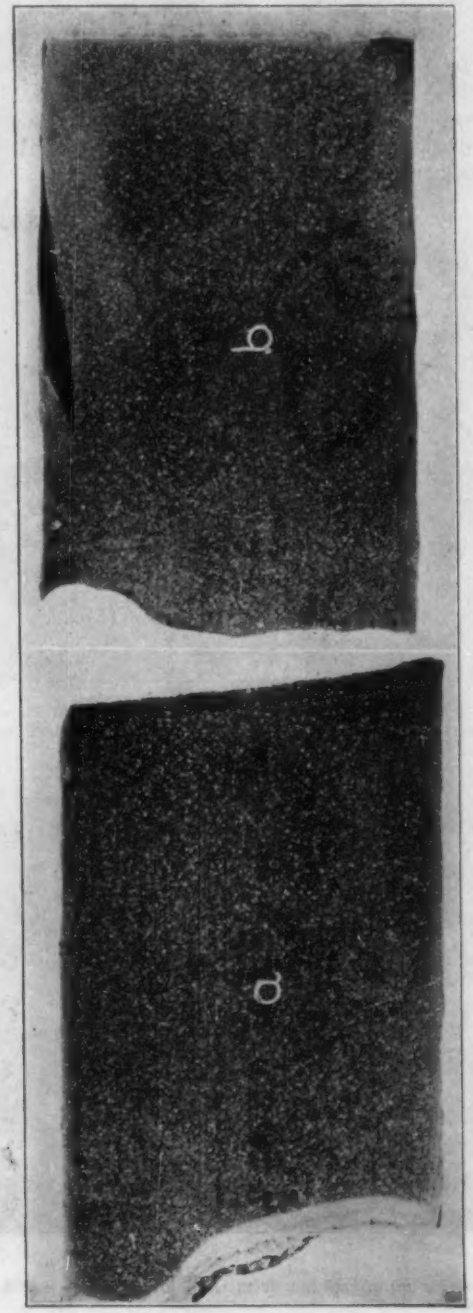
a

Fig. 7—Microstructure of cast iron from rail joint 13–4; a — unetched.

b

Fig. 7 — Microstructure of cast iron from rail joint 13–4; b — etched with 2 per cent alcoholic nitric acid.

None of the above examinations showed anything very striking or unusual in the cast iron. In tensile strength the iron is somewhat lower than that specified by A. S. T. M. for heavy castings (Spec. A48–18, light castings 18,000; medium castings,

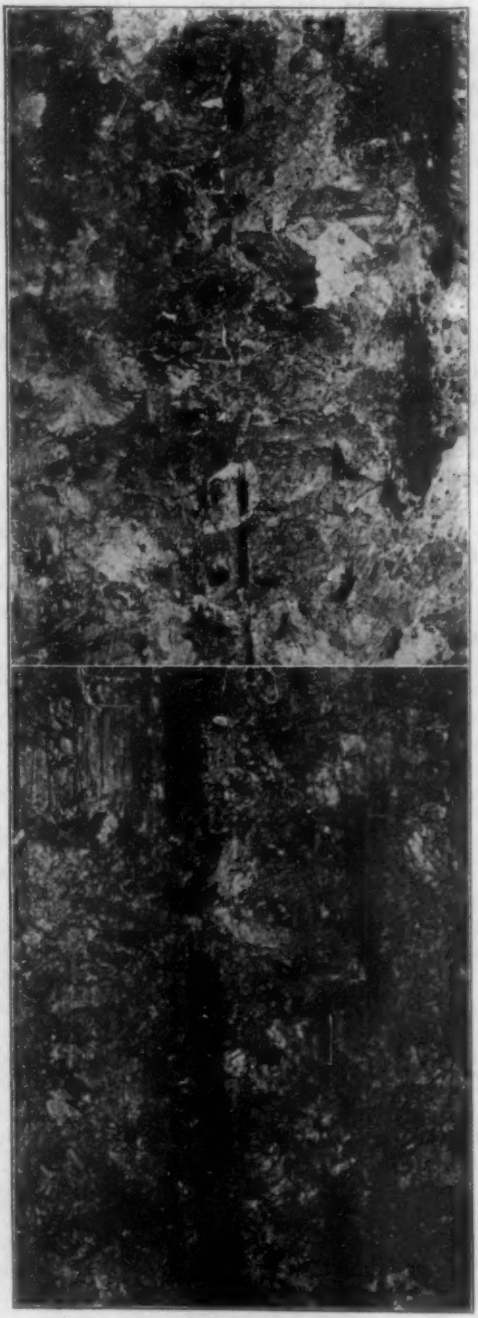


8–13

8–12

Fig. 8 — Vertical longitudinal sections of the head of the two rails. Etched with ammonium persulphate, × 2.

21,000; heavy castings, 24,000 lbs/in^2; a heavy casting is defined as one having no section less than two inches in thickness).



8–13

8–12

Fig. 9 — Microstructure of the two rails at the points "a" and "b" indicated in Fig. 8, × 100.

Special Examination:

Two of the seam weld joints (8–12 and 8–13' made under supposedly the same conditions when tested under the drop test gave very different results. 8–12 broke under the 4th drop whereas 8–13 withstood only one blow. It was suggested that perhaps instructions had not been followed in making the joints and that the rail steel used was not the same in both cases as had been intended.

A chemical analysis was made of the two with the following results:

	8-12 Per Cent	8-13 Per Cent
Carbon	0.74	0.74
Manganese	0.69	0.73
Phosphorus	0.019	0.039
Sulphur	0.044	0.037
Silicon	0.16	0.20

Although the two compositions were not found to be identical, the differences are not such as would account for the marked differences obtained in the drop test of the assembled joints assuming that the structural conditions of the two rails were not essentially different.

In Figure 8 are given micrographs of vertical longitudinal sections of the head of the two rails. These show that there was no pronounced difference in homogeneity (segregation streaks, etc.) in the two rails. While Fig. 9 which gives typical micrographs of the center of the head in each case shows that the microstructure in the two cases did not differ in any very marked respect.

On the whole, the results do not indicate any pronounced difference in composition on structure of the two rails and suggest that some other variable is responsible for the differences in the drop-test results of these two particular specimens.

GEORGE K. BURGESS, Director.

December 8, 1924.

EXAMINATION OF SECTIONS FROM WELDED RAIL JOINTS

Report of Union Carbide and Carbon Research Laboratories

LONG ISLAND CITY, N. Y., *January* 30, 1925.

Eight sections of different types of rail joints were received from the Committee on Welded Rail Joints, including a small piece taken from a cast iron weld. All except one, a bar resistance weld, were stamped with serial numbers by that committee, and the numbers are indicated on the photographs which were taken of each specimen. These serial numbers are the same as those on the welds in Bulletin No. 2 issued by the above committee, which should be consulted for details and methods of making the welds.

The types of welds received were:

3 butt resistance welds as shown in Figures 1, 2 and 3.
1 bar resistance weld, Figures 4, 5 and 6.
1 seam weld, Figure 7.
2 thermit welds, Figures 8, 9 and 10.
1 section from a cast iron weld, Figure 11.

Our examination of these joints was confined to the use of deep etching and the microscope.

The system followed in marking the sections cut for examination was as follows:
R represents the general heading "rail joints."
D represents a deep etch specimen.
M represents a microscopic specimen.

The M specimens were always taken from the D specimens, so for example, RM6 is the microspecimen taken from deep etch specimen RD6.

The deep etch specimens marked RD1 to 6 were taken in representative sections of the various joints to show the general character of the steel and weld. The location and designation of each of them are shown on the appropriate photographs, while the deep etch specimens themselves are shown in Figures 12 to 17.

Each of the specimens was taken so as to include the joint and the extent of the heat effect with the exception of Figure 13A, which is a special section and is fully discussed later.

From several of the deep etch specimens and from other parts of the joints, specimens for microscopic examination were taken. These are marked RM1 to 10, and are shown on the appropriate photographs. Our aim was to determine the extent and result of the application of the heat in the different welding methods, and we have avoided any comparisons between the different welds.

Specimen 11–24, shown in Figure 1, is a butt resistance weld which failed so as to leave part of the weld intact, thus giving us an opportunity to study the weld accurately.

Figure 18 shows a general view of the union. It consists of a sharply outlined zone that has been decarburized by the heat and slag, and that became the weld metal during fusion, together with a large number of inclusions lying parallel to the joint. These are shown more clearly in Figure 19 which is unetched. Occasionally these inclusions appear in the edge of the base or undecarburized metal. In the weld metal, they are noticed both in the pearlite grains and at the ferrite grain boundaries, but those in the base metal are wholly at the grain boundaries. They are probably the slag which is formed from the borax or flux during welding, and that are trapped in the weld. Beyond the decarburized zone, the usual heat effect is present, consisting of large grains near the weld with progressively smaller ones as

the distance from the weld increases, until the zone is reached which marks the limit of the changed structure. Beyond that, the steel is practically unaffected.

Fig. 1 — View of butt resistance weld No. 11–24 as received. The positions of the test pieces are indicated.

The surfaces of the butt resistance welds 11–28 and 11–12 were carefully scraped with a fine file. Microchemical examination revealed that there was a large quantity of sodium carbonate present in the scrapings. No trace of borax was found, although it was reported to have been used as a flux. One interesting point was noticed in this specimen. The piece was polished as well as possible, with dry alumina. Of course this did not produce a mirror finish, but left the surface mottled. However, a large number of inclusions were found such as shown in Figures 20 and 21. These

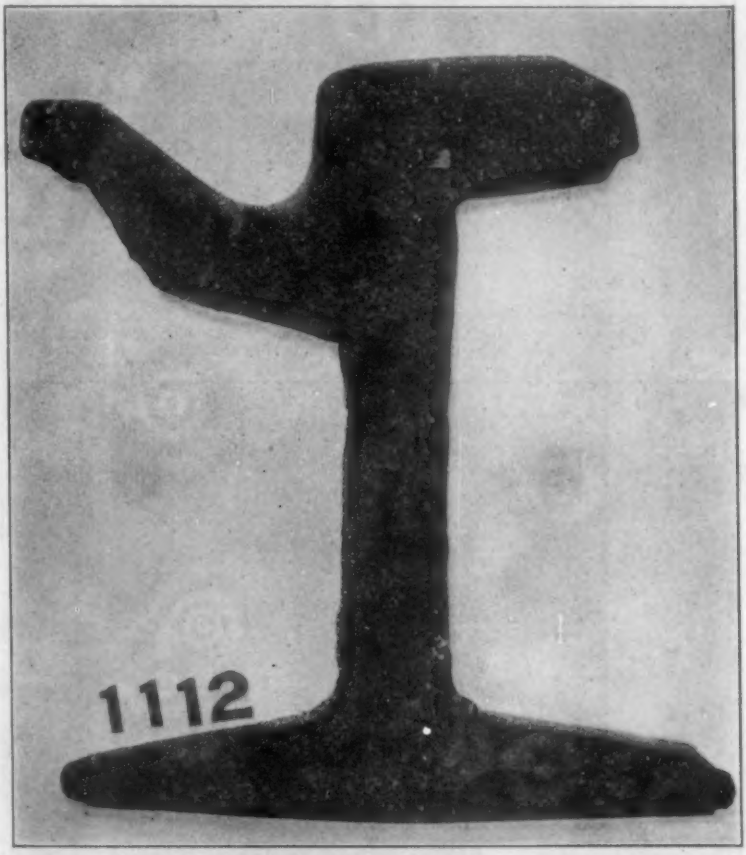


Fig. 2 — Face of butt resistance weld No. 11–12, as received.

inclusions were entirely different from those mentioned before; they are light gray and do not appear after wet polishing. They were unattacked by picric acid in alcohol, but disappeared after being immersed in boiling water for five minutes. This observation is of some interest, as it seems to show that water soluble material exists in the base metal near the weld. It is possible that some of the flux has found its way through small passages and cavities, though we did not try to follow the matter up. Although the effect of these particles, if they were the sole inclusions, would be somewhat detrimental to the strength of the steel, they are of little consequence in comparison with the large number shown in Figures 18 and 19. This

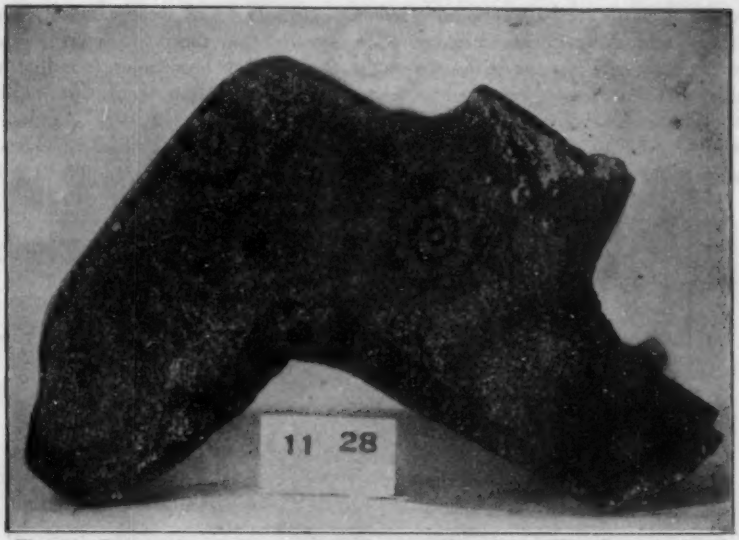


Fig. 3 — Face of butt resistance weld fracture No. 11–28. The flange and web have been cut off, leaving only the tread.

Fig. 4 — Fracture of bar resistance weld, as received. There was no number on this specimen.

broad streak of dirt extending over the entire cross section would seem to account for the path of rupture in this type of joint.

An examination was made of the fractures of the other two butt resistance welds, and also of the material adjacent to the fracture. The fracture was intragranular with a slightly decarburized edge, and many secondary cracks filled with inclusions. These secondary cracks, while doubtless caused by the breaking of the joint, were

Fig. 5 — Top view of bar resistance weld specimen.

probably filled with rust or dirt from the long exposure of the specimen to the elements, as no similar cracks were found in Specimen RM1A.

Figures 24 to 32 are photographs in the bar resistance weld. Figures 24 and 25 are views of the union between the shim and the rail web, and between casting and shim. The former is much freer from oxide dots than the latter, but has a larger number of large nonmetallic inclusions. Both are quite similar to the butt resistance weld shown previously.

this specimen.

Fig. 6 — Side view of bar resistance weld specimen showing fracture of cast steel supporting head.

In studying Figure 4, which is a view of the fracture of this weld, we noticed that the web of the rail seems to have lost its individuality — in fact its contour cannot be made out at all for a distance of two and one-half inches. The fracture is large grained and columnar, similar to the fracture of a steel ingot. A section about ½"

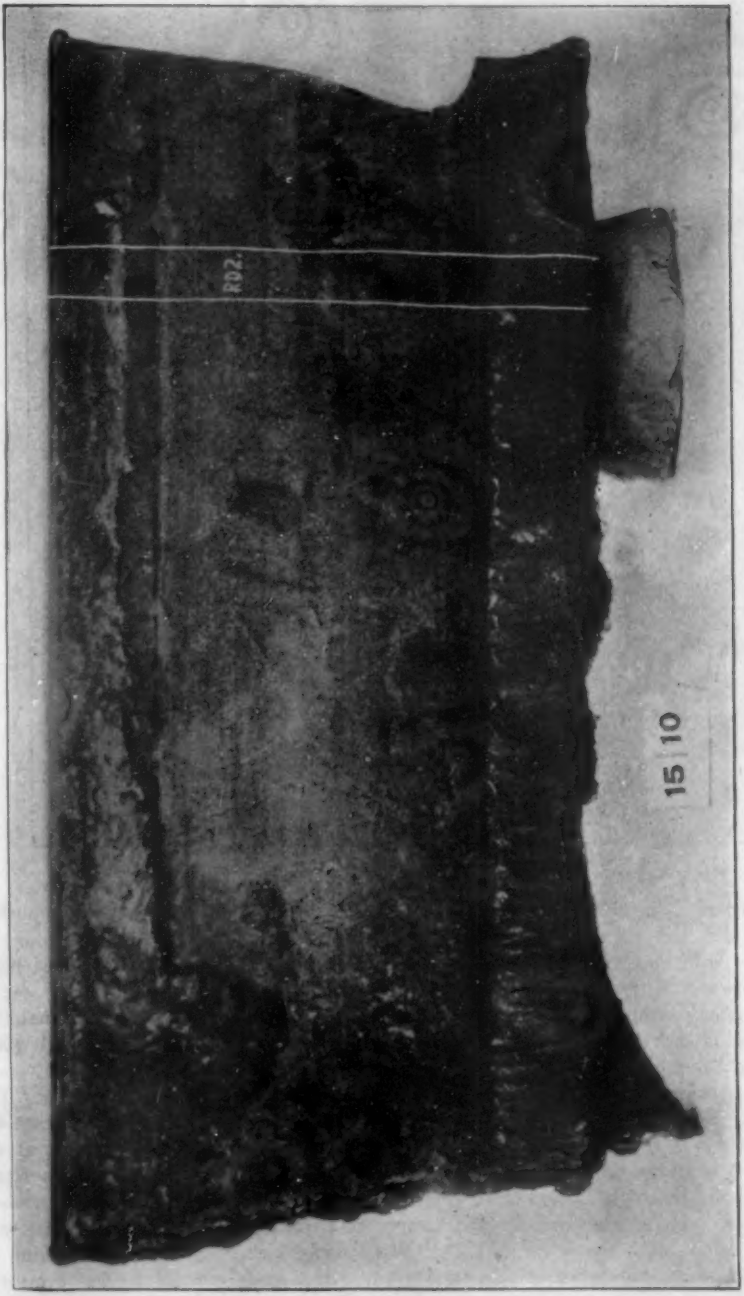


Fig. 7 — View of scam weld specimen No. 15-10 as received, showing top view of one side of rail base.

from the fracture was ground smooth and etched, and is shown in Figure 13A. The section is not complete because specimen RD3 had been cut off previously. Directly between the spots at which the electrodes seem to have been applied, the rail web

Fig. 8 — Face of fracture of thermit weld specimen as received, No. 15–20.

probably has been in a pasty condition, as has also part of the steel bar. The outline of the web has been completely destroyed on one side by intermixing of the rail material with that of the bar, while part of the web has been squeezed out of place into the space between the bar and the under part of the flange, as shown at spot 5. The original outline of the rail is shown in dotted lines. Figure 31 shows that this material is extremely spongy, as would be expected of high carbon steel when overheated.

Two specimens RM3C, RM3D were polished and examined microscopically. The material in the two bars did not seem to be extraordinarily changed, except that the grain size was very large as might be expected from Figure 13A. The part of the web that has been amalgamated with the bar is in a condition that is always found with overheated high carbon steel. At the grain boundaries are large quantities of inclusions rejected there under the temperature conditions. These inclusions are shown better in Figures 26 and 27. With these inclusions is a broad film of cementite, completely surrounding each grain. It is quite unusual to find cementite collected at the grain boundaries of a .70 or .80 C steel. The cause of its location there must be laid to the peculiar conditions and rapid rate of cooling. This type of structure is typical of the entire area around spots 3 and 4, diminishing in intensity as the bar structure is approached, and increasing as the fracture is approached.

Fig. 9 — Side view of thermit weld specimen No. 15–20.

This structure is not only unusual, but the presence of cementite has a distinctly harmful effect. Figure 29 clearly shows that the fracture has taken place through these grain boundaries. That this type of failure would take place seems quite

evident when the brittleness of the cementite and the presence of the large number of inclusions at the grain boundaries are considered. Either of these conditions alone is quite sufficient to provoke failure while the two together assure it.

Another view of the fracture is shown in Figure 30. Here the cementite films are absent, and there are fewer inclusions at the grain boundaries, so that failure has taken place through the grains themselves. It will be noticed that the lower part of the fracture has taken place through the web, while the upper part of the web is a network of cracks reducing the strength of the rail at that point.

Figure 32 shows what has happened at spot 2, where the electrode was applied to the steel casting. Whether this burnt structure was a direct result of the process or not we did not determine. However, this matter would bear investigation. In regard to this type of weld, and this weld in particular, the question might be asked, whence came the material shown at spot 5? It has been pushed there from some place, yet there do not appear to be any holes large enough to supply all that metal. As it

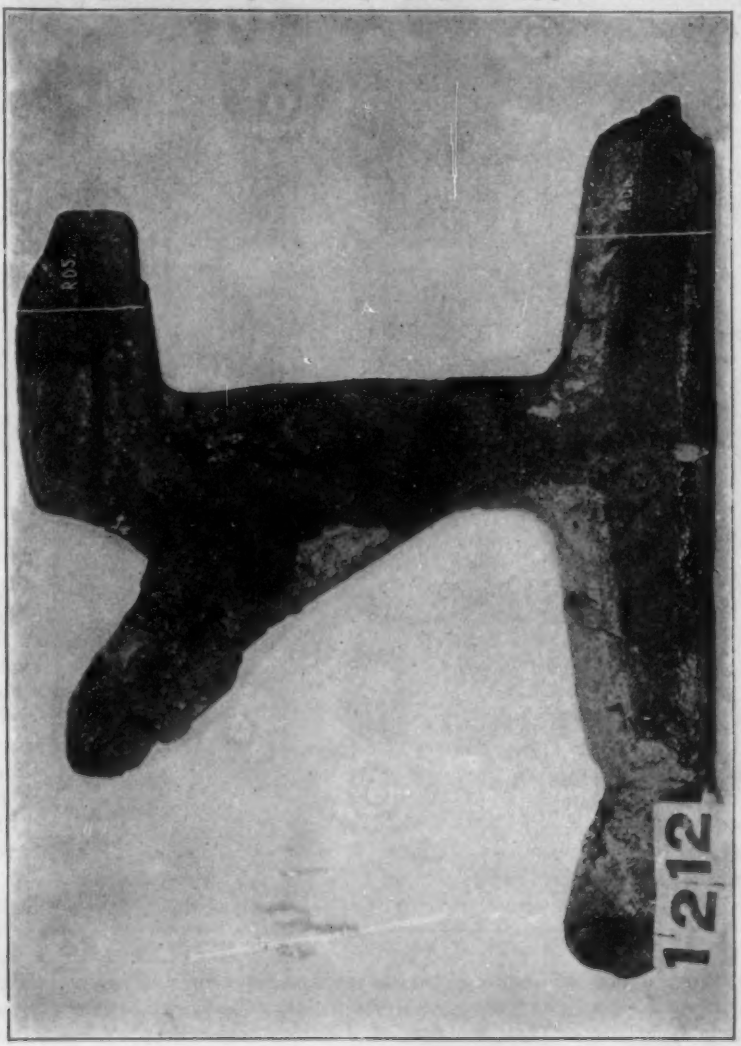


Fig. 10 — Face of fracture of thermit weld specimen No. 12-12, as received.

Fig. 11 — View of piece of cast iron weld No. 11-18. Full size.

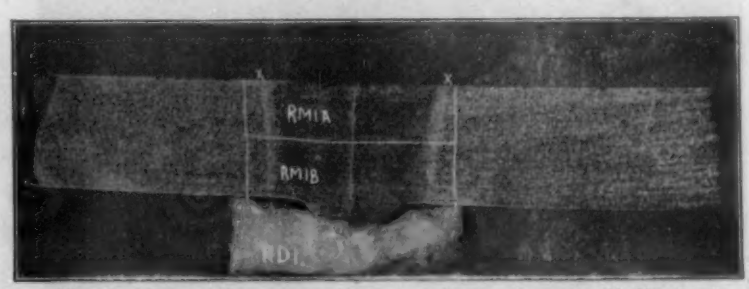


Fig. 12 — Deep etch specimen RD1, from butt resistance weld No. 11-24.

came from the web by being pushed out, and there is no corresponding dent in the steel bar, the presence of this excess material seems to bear witness to the looseness with which the structure is held together throughout this region.

The seam weld has the same general characteristics as the other types, but because of the intensity and localness of the heat, its short time of application and its rapid cooling, the changes in structure are compressed into a shorter space. Figure 14 shows this, and Figure 33 comfirms it. Figure 33A shows the rejection of impurities to the grain boundaries, as in other types of welds, but neither so extensive nor so marked.

The thermit welds show some interesting structures. Figure 34 is in general very similar to Figure 33, though the dendritic and columnar structure in the weld is much more marked. Figures 16 and 35 shows this structure in the weld metal. In specimen RM6A there were several areas of poor fusion as at Figure 10, A, Figure 17, B, and Figure 16, C. The former two are due to trapped slag or other foreign matter,

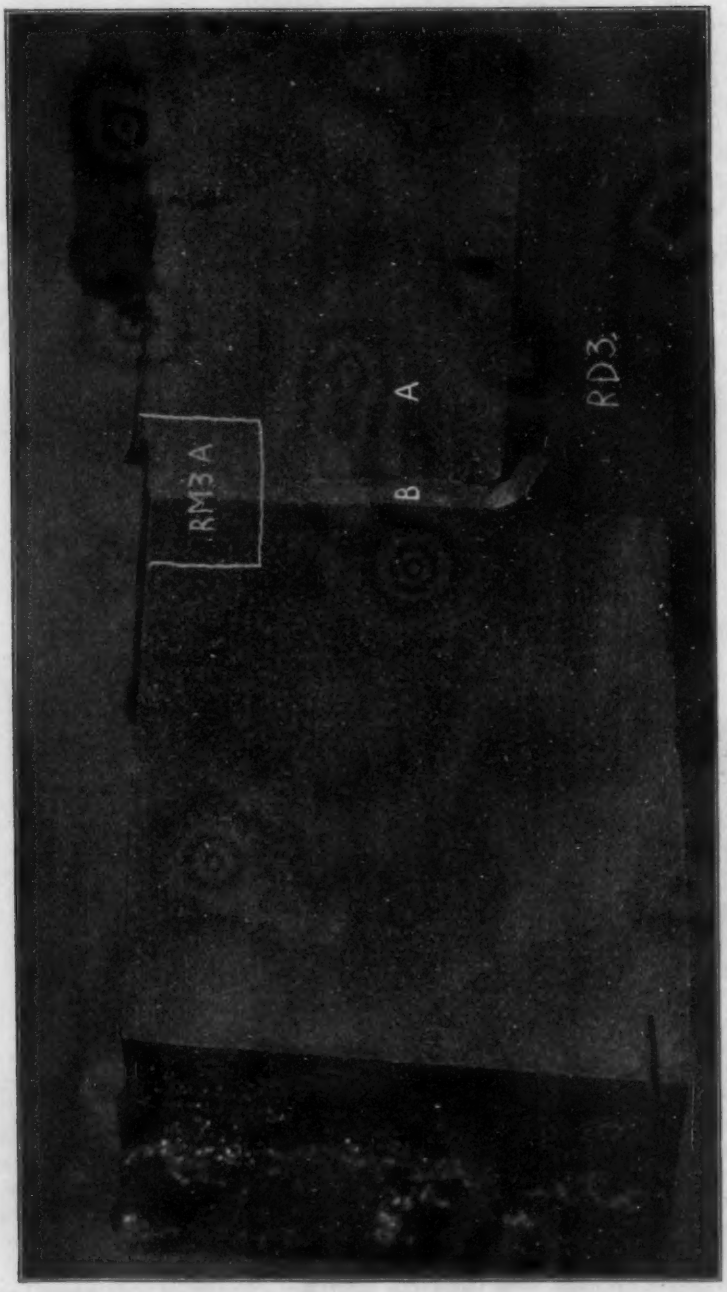


Fig. 13 — Deep etch specimen RD3 from bar resistance weld. This shows steel support casting A, shim B, and rail section. Full size.

while the latter seems to be due to there not being enough hot metal at the corner to cause fusion. Failure occurred through the base metal in Figure 17, and through the union of base and weld metal in Figure 16. In the latter case failure would be expected, as such a sudden change in outline induces a corresponding decrease in

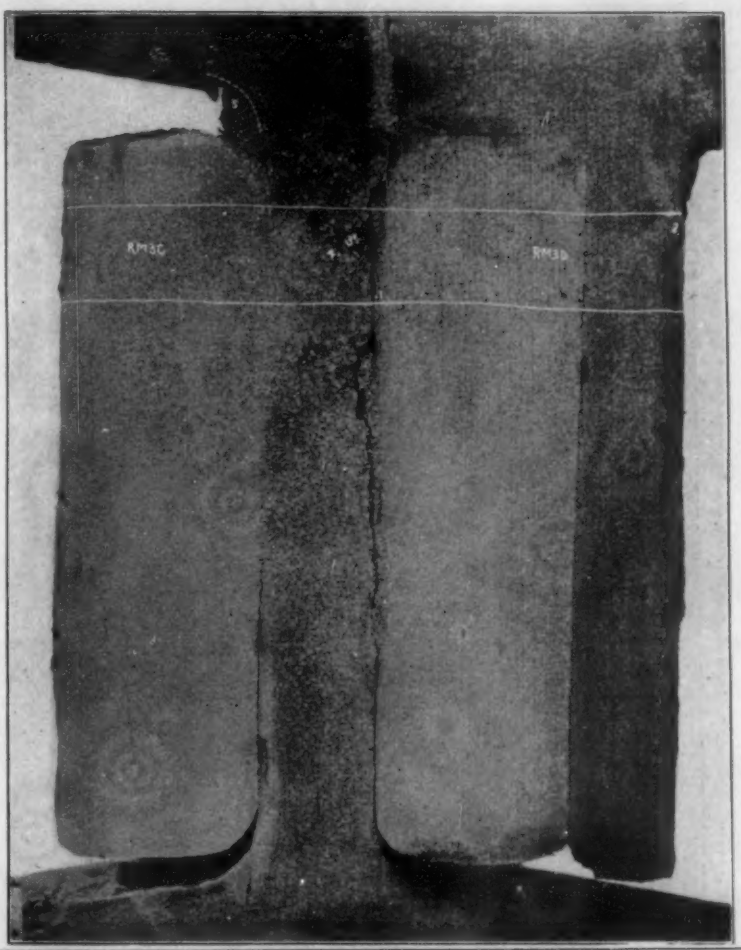


Fig. 13A — Deep etch section through bar resistance weld, one-half inch from the fracture. Note the lack of union at the bottom of the web on both sides, and the crack on the right side of the web. This crack may have been formed when the joint was tested.

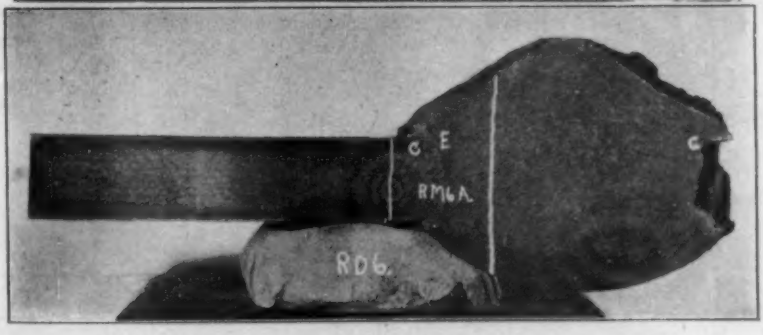


Fig. 16 — Deep etch section RD6 from thermit weld No. 12-12. Full size.

resisting power. Figure 36 shows the cracking that occurred in specimen RM6A at E, Figure 16, probably because of the poor fusion and the high localization of stress.

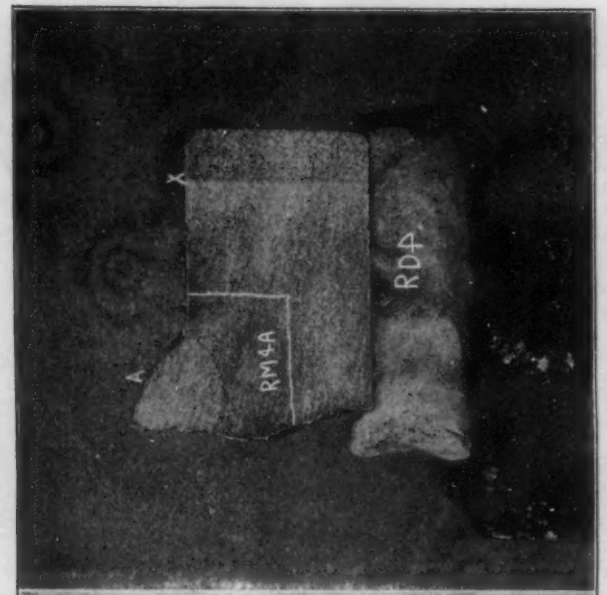


Fig. 15 — Deep etch section RD4 from thermit weld No. 15-20. The light area A is the thermit metal. Full size.

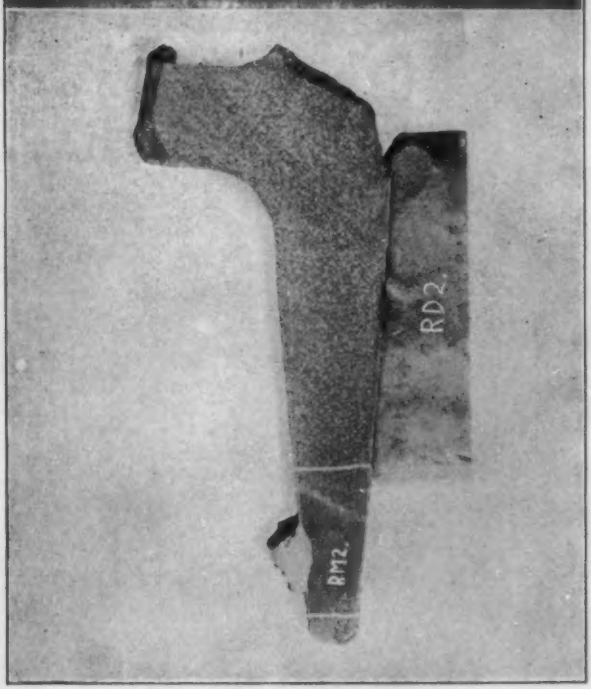


Fig. 14 — Deep etch section RD2 from seam weld No. 15-10.

Another contribution to failure at the union between the base and weld metal is the condition shown in Figure 37. This shows the inclusions that have been forced to the grain boundaries during the high temperature just next to the weld. Figure 38 is a

photograph of a crack that started very close to the area shown in Figure 37, and which is probably due to the inclusion which may be seen in the crack.

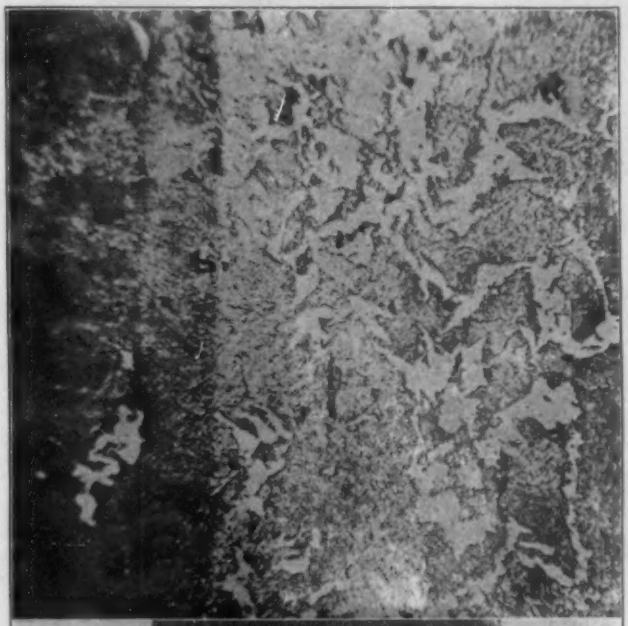


Fig. 18 — Specimen RM1A. The union between two rail ends in a butt resistance weld. The region of welding has been decarburized by the heat. 430X.

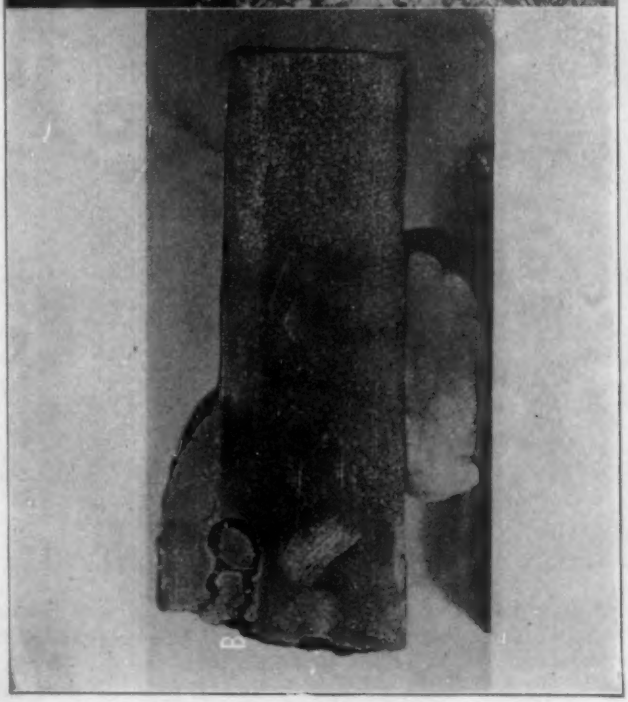


Fig. 17 — Deep etch section RD5 from thermit weld No. 12-12. Full size.

Fig. 19 — View of butt resistance weld unetched. The zone of fusion is clearly outlined by the number of inclusions. These inclusions were shiny and black, and seem to be the slag from the flux and oxide. 100X.

Fig. 20 — Specimen RM1A. This piece was polished on dry alumina. A few of the gray inclusions are shown. Unetched. 430X.

This rejection of impurities to the grain boundaries in the base metal just next to the weld is found to occur in all welds. Its effect may be of little or great importance, depending on the importance of strength in the welded piece. As it is the result of the applied heat, it cannot be avoided, and must be considered in the designing and

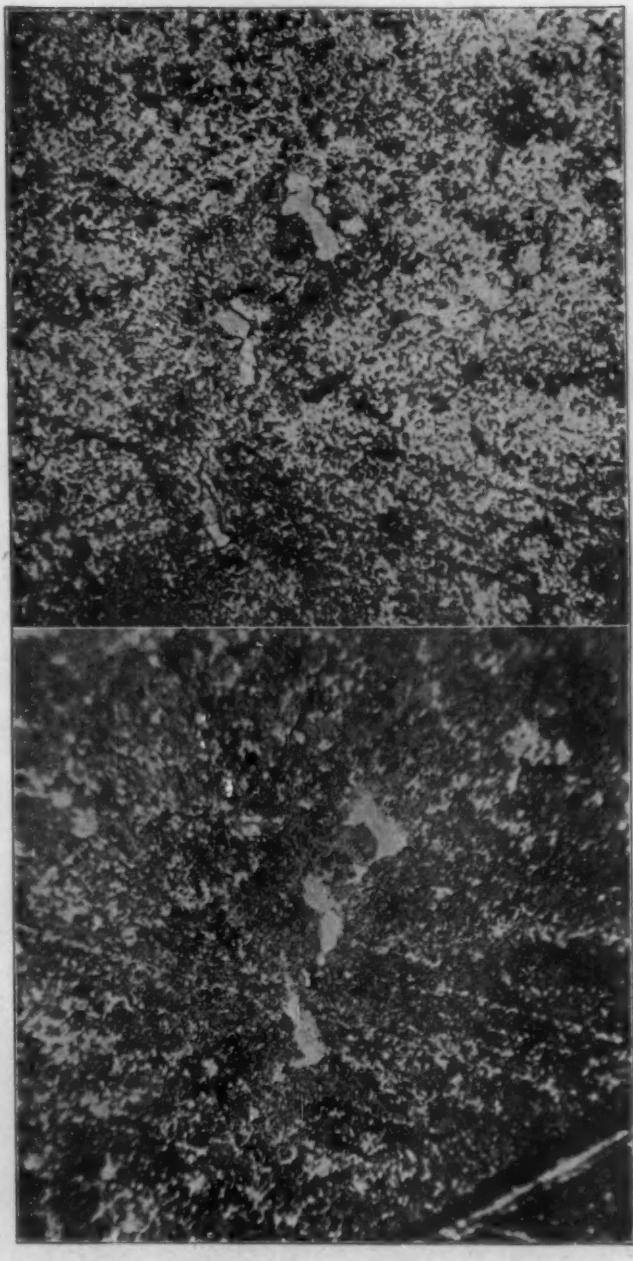


Fig. 21 — Specimen RM1A. Another group of gray inclusions, this time in the base metal. Unetched. 430X.

Fig. 22 — Same view as Figure 21, but etched with picric acid in alcohol. The inclusions were unattacked. 500X.

making of the weld, though evidently the cleaner the base metal, the less the effect. Figure 39 shows, as nearly as possible, an average view of the inclusions in all the rail sections This is not to be taken as exact, because of the difficulty of selecting an average view. With this in mind, it is probably fair to say that the rail metal was of average quality.

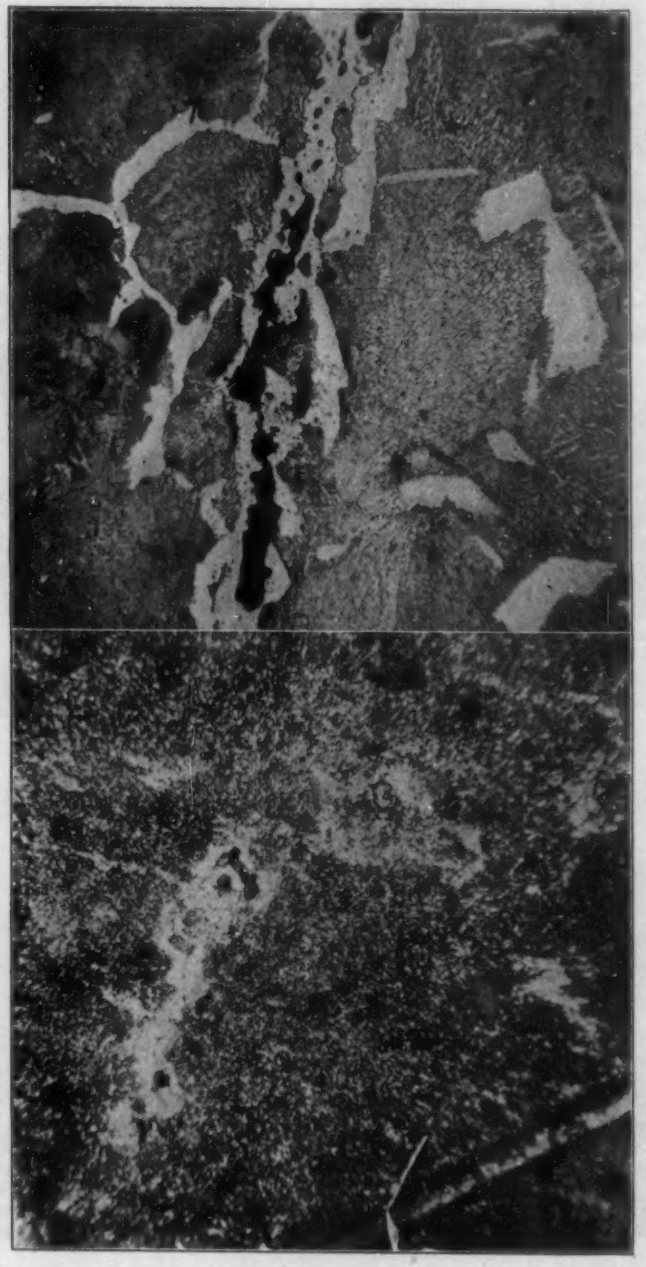


Fig. 23 — Same view as Figs. 21 and 22, but immersed in boiling water for five minutes. Inclusions are removed. 430X.

Fig. 24 — Specimen RM3A. Weld between the rail web and shim. The inclusions are mainly glassy. 430X.

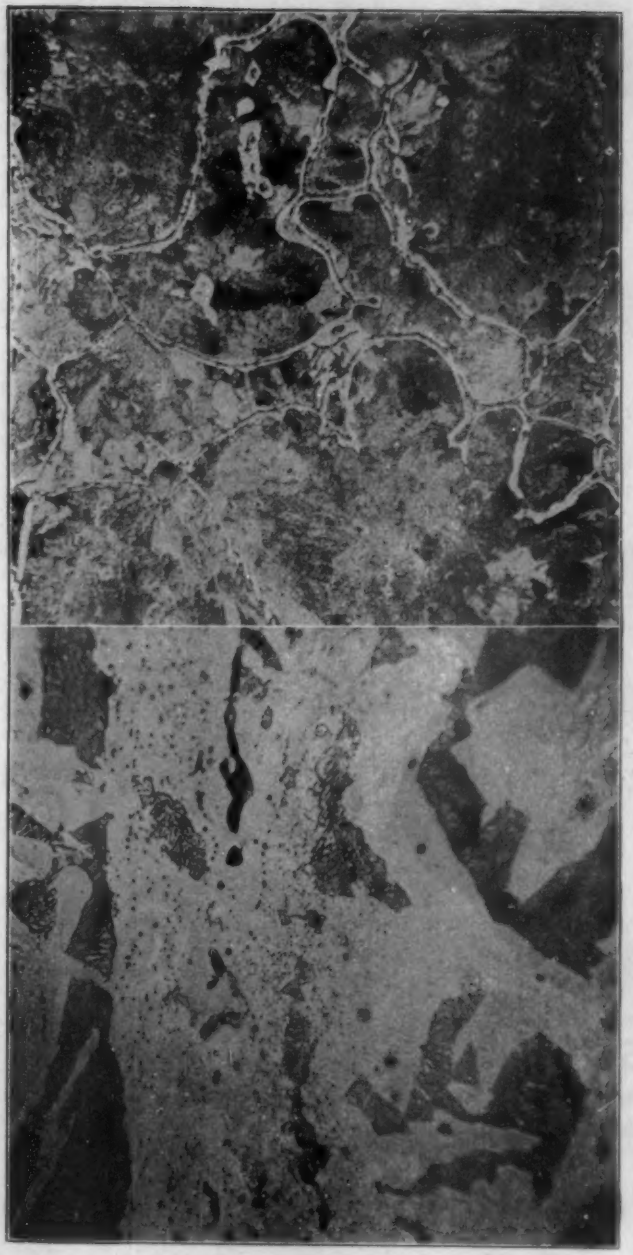


Fig. 26 — Specimen RM3C. A view of the steel in the overheated section of the web, spot 4, Figure 13A. The grain boundaries are outlined with impurities rejected there, while at high temperature. 100X.

Fig. 25 — Specimen RM3A. Weld between shim and the casting. Large number of oxide dots but fewer inclusions. 430X.

The specimen of cast iron which we received was a piece that had broken from cast iron weld number 11–18. A chemical analysis gave the following composition:

Carbon	3.55
Silicon	2.80

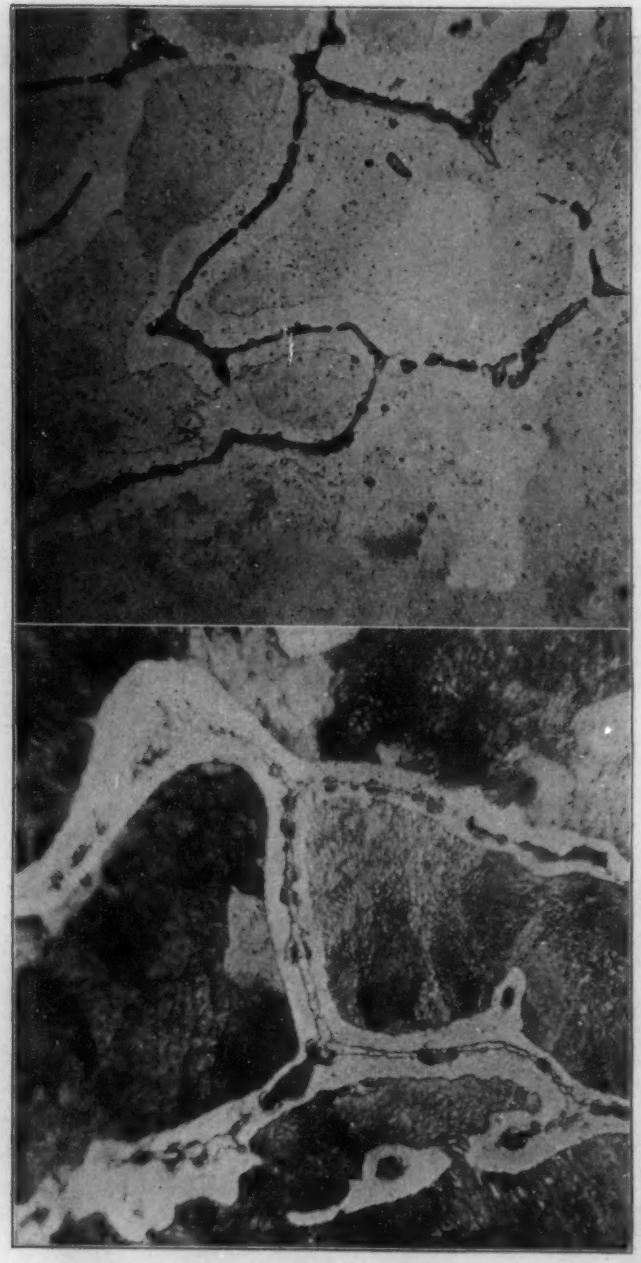


Fig. 27 — View in same field as Fig. 28. The gray spots are inclusions while the band is cementite. 430X.

Fig. 28 — Same area as in Fig. 27 but etched in boiling sodium picrate. 430X.

Manganese	0.52
Phosphorus	0.30
Sulphur	0.072

The miscroscope shows the iron to be made up of a matrix of ferrite and graphite.

Fig. 29 — A view at spot 3, Figure 13A. This shows that fracture did take place through these damaged grain boundaries. 100X.

Fig. 30 — View of fracture of rail web, away from the overheated zone. This fracture is intragranular, which seems to show that rupture occurred during testing. Rm3D. Spot 1. 100X.

Because of the minute flakes in which the graphite exists, the structure is much stronger than ordinary cast iron. The fine close grain also results in a strong tough iron, and with the chemical analysis, indicates a material quite suitable for the purpose.

S. W. MILLER.

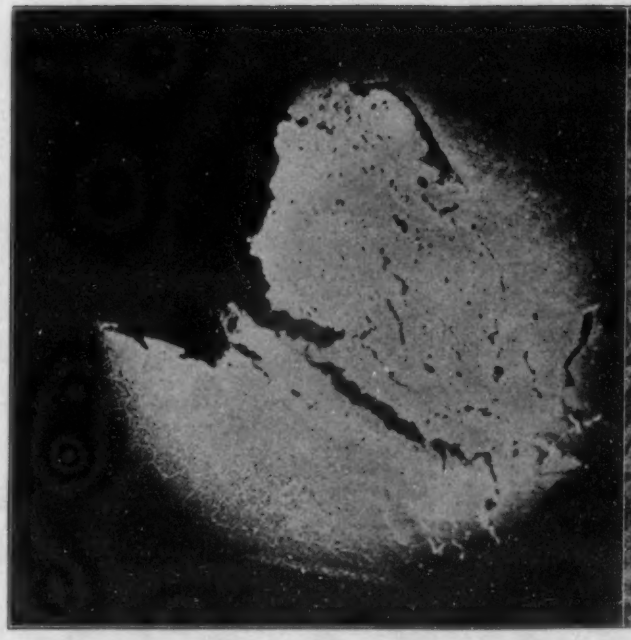


Fig. 31 — A view at about 25X of the area at spot 5 in Figure 13A. The porous material A, is entirely from the web and not from the bar B.

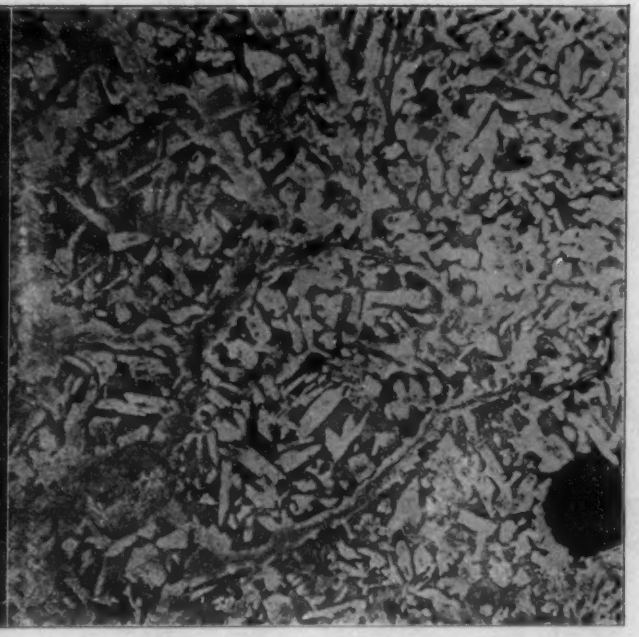


Fig. 32 — A view at spot 2, Fig. 13A. The grain boundaries have been burned, possibly by the action of the electrode. 100X.

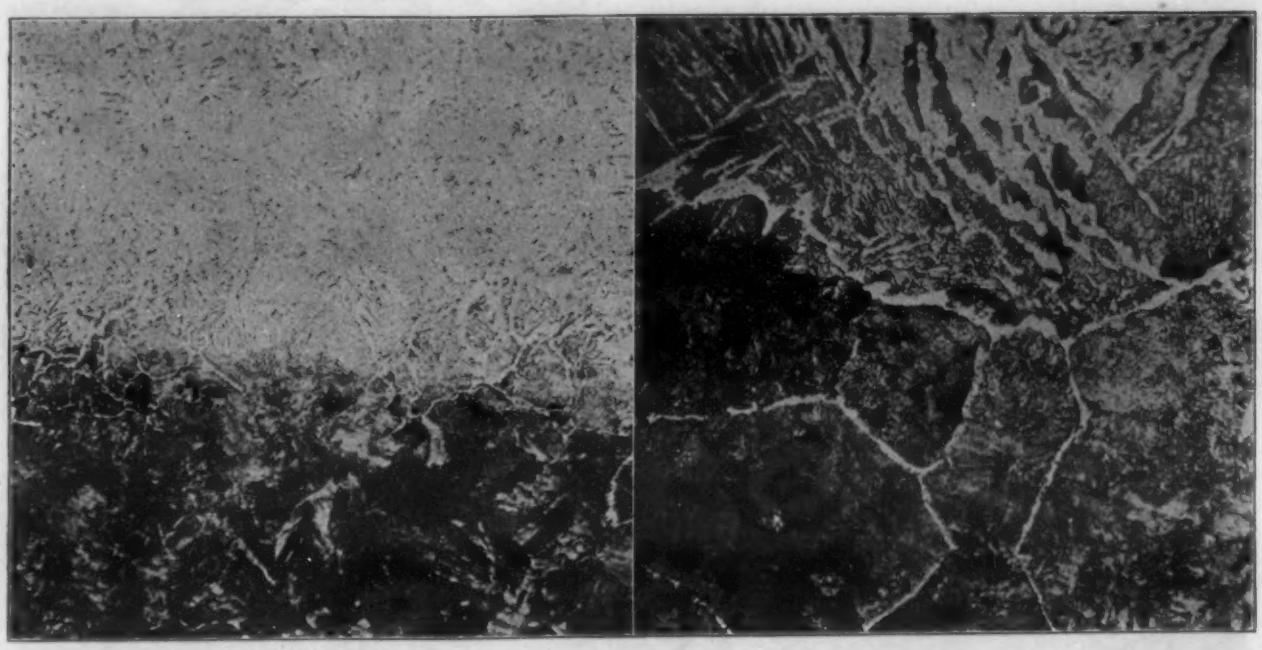


Fig. 33—View of line of union in seam weld. Weld metal above. 100X.

Fig. 33A — RM2. A view of a number of minute inclusions forced to the grain boundaries by the heat of welding. 570X.

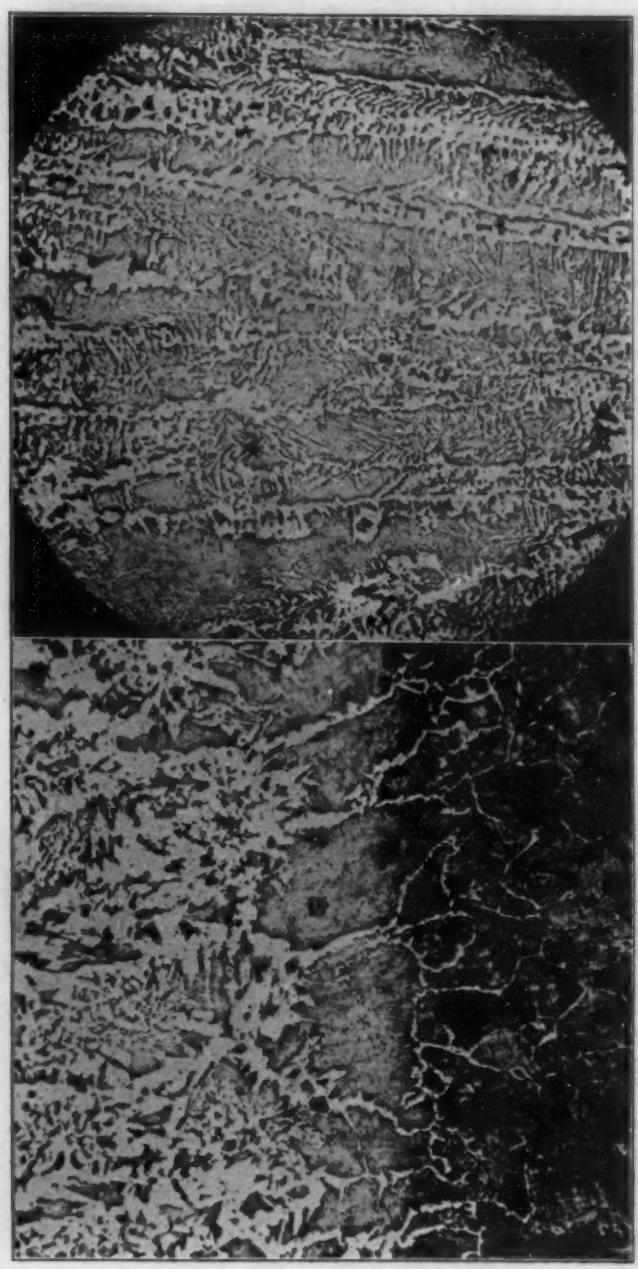


Fig. 34 — Specimen RM4A. Weld between rail and thermit. The upper part is the weld metal. 100X.

Fig. 35 — Specimen RM4A. Dendrites in thermit weld. 50X.

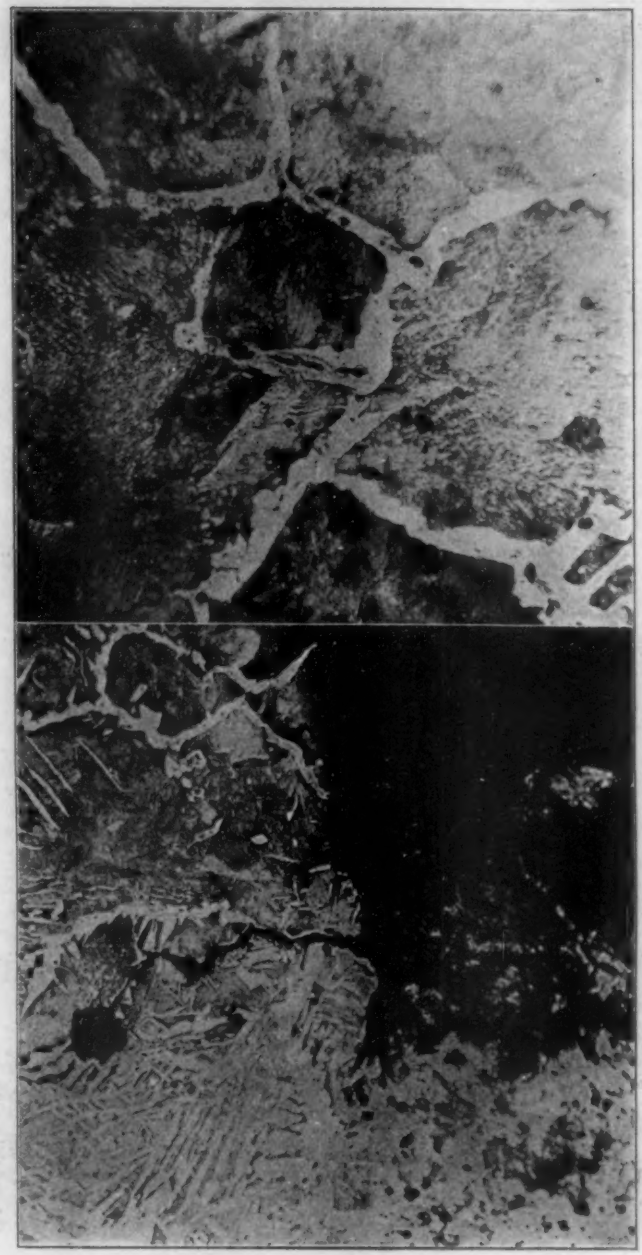


Fig. 36 — Specimen RM6A. A crack at spot E, Fig. 16. 100X Fig. 37 — Specimen RM6A. Rejection of inclusions to the grain boundaries in the base metal just next to the weld. 430X.

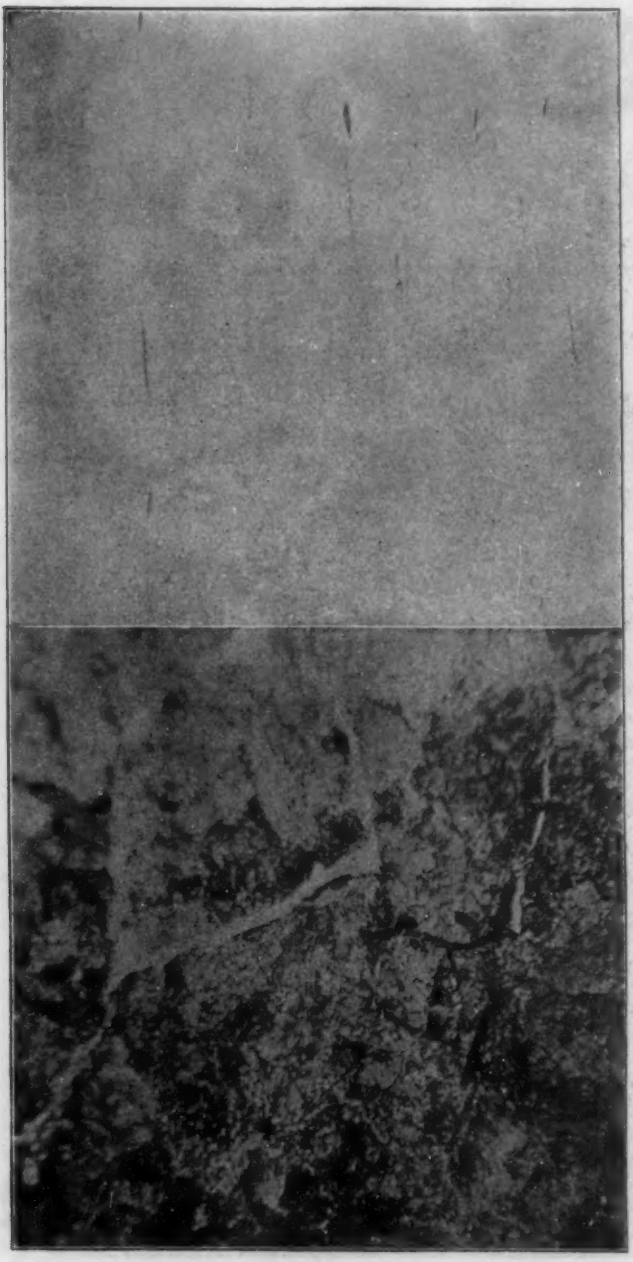


Fig. 39 — Average view of inclusions in all rail sections. Unetched. 100X.

Fig. 38 — Minute fracture that occurred in the base metal very near to the area shown in Fig. 37. There is a round inclusion in the crack. 570X.

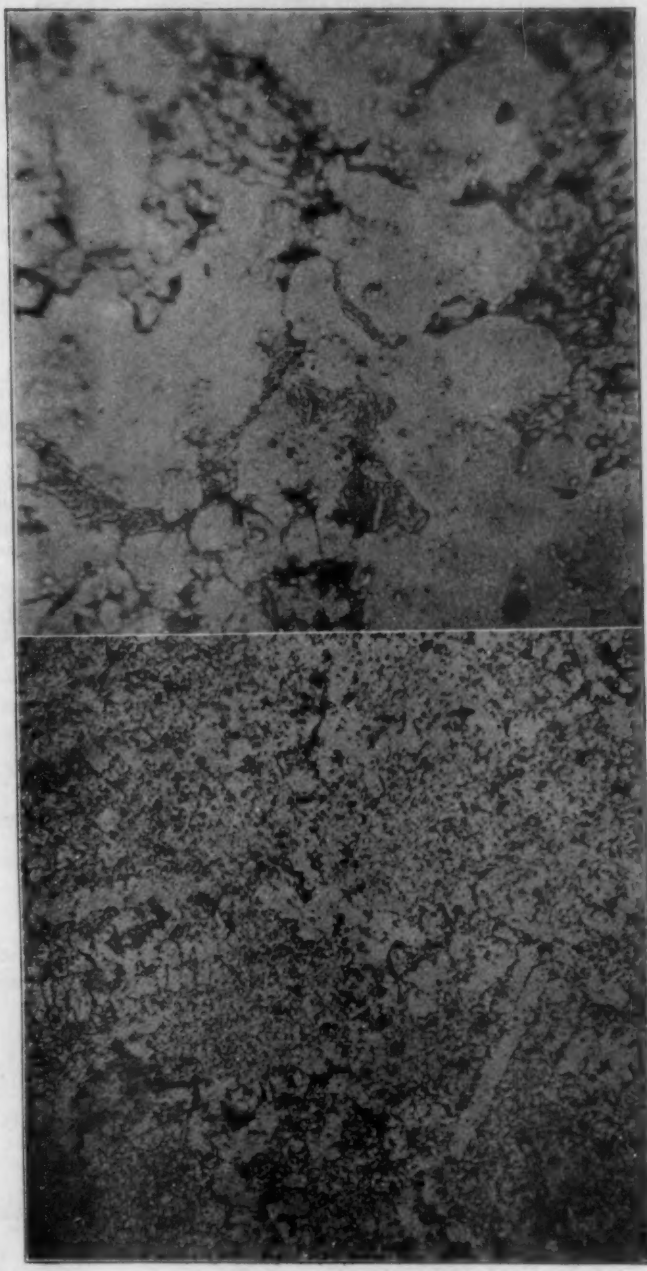


Fig. 40 — Average view of cast iron. The structure is mainly ferrite and graphite. 100X.

Fig. 41 — View in the phosphide eutectic areas. There is some pearite associated with it. 430X.

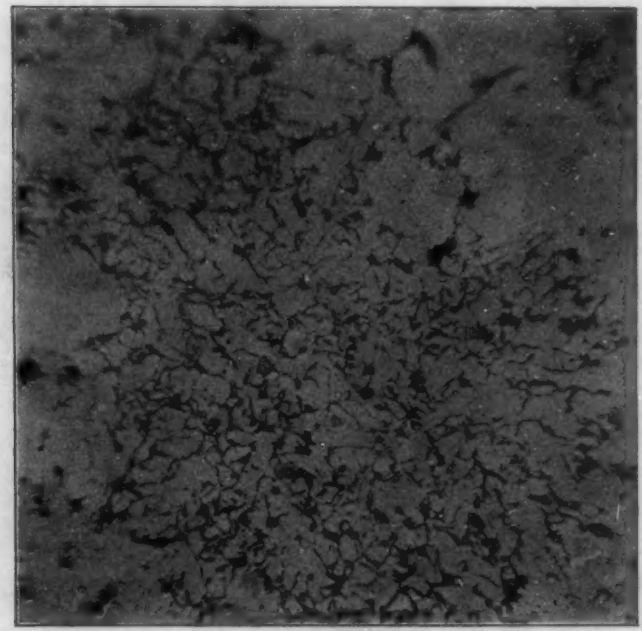


Fig. 42 — View within graphitic areas. The graphite flakes are quite fine and short. 430X.

APPENDIX A

REPORTS OF RAIL WELDING & BONDING CO.—REPEATED IMPACT TESTS ON TEST JOINTS SUBMITTED BY THE UNITED RAILWAYS & ELECTRIC CO. OF BALTIMORE, MD., AND THE BOSTON ELEVATED RAILWAY CO., BOSTON MASS.

Note: The following data were furnished to the Committee by the R. W. & B. Co. The Committee does not assume any responsiblity for the information contained therein. In regard to the report of tests of the joints furnished by the United Railways & Electric Co. of Baltimore, the Committee has been requested by that company to point out that the joints as made up do not accord with their usual practice.

UNITED RAILWAYS & ELECTRIC CO., OF BALTIMORE, MD.

1. The following description of the test joints referred to in this report is taken from the letter dated August 12, 1924, from Mr. W. W. Wysor to Mr. E. R. Alexander:

"We have made up twelve sample joints for testing and which we are shipping to you by freight prepaid. There are three series, A, B and C and four joints to each series, numbered 1 to 4. All joints are made up of two pieces of rail, each 16-inches long making the total length of joint 32-inches; rail section B. S. Co. 122–107A, welding rod, Rail Welding and Bonding Company grade 200. The series and joint number are stamped on the head of the rail and there is also an arrow to indicate the north end of the joint. Hand feed process was used in all cases and single welding only was employed.

"All joints are made up in accordance with our standard practice as to location of seams but we have omitted base plates for the reason that that more or less complicates the test and in this particular lot of joints what we are after is to determine the value of preheating or postheating and the value of working the hot metal by hammering.

"The joints were made up as follows:

Series A — No. 1 No preheating or postheating.
No. 2 Preheated.
No. 3 Postheated.
No. 4 Preheated and postheated.

Series B — Four joints same as Series A, except that all seams were worked with pneumatic hammers.

Series C — Four joints same as Series A, except that the head of the rail is planed and the base of the wide plate also planed in accordance with the attached blueprint (Fig. 1) and all seams were worked with pneumatic hammer.

The number of inches of welding rod used in each case was as follows:

Series A — No. 1 — Base Seams — High side S. 12" N. 15".
Low side S. 12" N. 12".
Head Seams — High side 21".
Low side 20".
No. 2 — Base Seams — High side S. 11½" N. 11½".
Low side S. 11" N. 11".
Head Seams — High side 29".
Low side 24½".
No. 3 — Base Seams — High side S. 12½" N. 14½".
Low side S. 11" N. 12¾".
Head Seams — High side 26".
Low side 29".
No. 4 — Base Seams — High side S. 12" N. 13".
Low side S. 11" N. 12".
Head Seams — High side 30".
Low side 25".
Series B — No. 1 — Base Seams — High side S. 12" N. 12".
Low side S. 13" N. 12".

		Head Seams —	High side 24".	
			Low side 24".	
	No. 2 —	Base Seams —	High side S. 12½"	N. 11½".
			Low side S. 12"	N. 12".
		Head Seams —	High side 28½".	
			Low side 27".	
	No. 3 —	Base Seams —	High side S. 11½"	N. 11½".
			Low side S. 16"	N. 13".
		Head Seams —	High side 26½".	
			Low side 24".	
	No. 4 —	Base Seams —	High side S. 11"	N. 14¼".
			Low side S. 17¼"	N. 13¼".
		Head Seams —	High side 26½".	
			Low side 22½".	
Series C —	No. 1 —	Base Seams —	High side S. 18"	N. 18".
			Low side S. 13"	N. 12".
		Head Seams —	High side 53".	
			Low side 29½".	
	No. 2 —	Base Seams —	High side S. 16½"	N. 17".
			Low side S. 13½"	N. 12".
		Head Seams —	High side 50½".	
			Low side 31".	
	No. 3 —	Base Seams —	High side S. 16½"	N. 19½".
			Low side S. 11½"	N. 13½".
		Head Seams —	High side 55½".	
			Low side 30".	
	No. 4 —	Base Seams —	High side S. 16½"	N. 19½".
			Low side S. 14½"	No. 12½".
		Head Seams —	High side 58".	
			Low side 30½".	

"Our preheating apparatus consisted of two Hauck torches one applied to each side of the joint. These were kerosene torches operating under an air pressure of something like 50 pounds.

"We also used a sheet iron oven to cover the joint which accelerated the heating and also made it more uniform. We had no accurate means of determining the temperature to which rails were heated, but our judgment was that it was between 600 and 800° F. Tin foil would readily melt when laid on the rail, but the rail was not hot enough to show red."

2. In a letter dated September 24, 1924, Mr. Wysor added the following explanation:

"Referring to the sample joints which we sent you for testing, we have discovered that our shopman in planing off the head of the rail for the series "C" joints made an error in the angle, which instead of being 55° was only about 41°.

"We discovered this when we made up an additional joint to test in a small way of our own, and we found to our chagrin that it was practically impossible to weld to the bottom of the groove. In fact, the welding extended only about ⅓ of the way in from the outside edge of the rail head."

3. The method of testing is described in "Investigation of Seam Welded Rail Joints" (January 1924 issue of the Journal of the American Welding Society). The essential conditions of the tests were as follows:

Weight of hammer	250 lbs.
Weight of anvil	2450 lbs.
Drop of hammer	10 inches
Blows per minute	70
Support of joint	½ inch leather strip directly on anvil.
Total length of joint	32 inches

Included in the summary of data, are the test data of joints H-84 and H-85 welded by the Rail Welding & Bonding Company for the purpose of comparison. These joints were welded in accordance with instructions as noted in our Bulletin 106.

It must be kept in mind that the tests described in this report were not intended

to bring out the effects of pre-heating and post-heating on the rail itself, but rather on the seam welds. In order to determine the effects of pre-heating, post-heating, staggered plates, staggered seams, etc., as regards stresses in the rails, we have devised a means for holding joints 68" long on supports having a span of 60". It is recommended that further test joints be made of such length (68") that they can be tested on this wide span. The test will be a very severe one, but it will bring out in

SUMMARY OF REPEATED IMPACT TEST DATA

Rail joints welded by Baltimore (U. R. & Elec. Co.)

Group No. Proc.	Our No.	Your No.	Total rod,* lbs.	Seam Weld Cracks						Max. blows	Plate Cracks Started		Remarks
				Started	Loc.	50 M	100 M	200 M	Max.		Wide	Narrow	
105	R-46	A-1	1.61	17,500	d-S	49"	(59")		59"	78,000			Not preheated or postheated
	R-48	A-2	1.73	6,500	c-S	34	(59)		59	94,800			Preheated
	R-51	A-3	1.86	22,400	d-S	1"	13½	(37½)	37½	167,900	131,400		Postheated
	R-47	A-4	1.82	1,650	c-S	(68)			68	38,700			Preheated and postheated.
106	R-42	B-1	1.70	24,000	c-N	21	(51½)		51½	67,000			Not preheated or postheated
	R-50	B-2	1.82	22,700	c-S	11	(57½)		57½	98,100			Preheated
	R-52	B-3	1.80	1,300	d-S	14¾	(60)		60	80,700			Postheated
	R-43	B-4	1.84	22,000	d-S	23	(61½)		61½	67,000			Preheated and postheated
Joints in series B are same as those in series A, except that all seams were worked with pneumatic hammer.													
107	R-44	C-1	2.52	40,000	d-N	½	18	(47)	47	160,000			Not preheated or postheated
	R-49	C-2	2.47	5,100	d-N	11"	23	(66)	66	125,000			Preheated
	R-53	C-3	2.57	13,200	c-S	34	(56)		56	79,200			Postheated
	R-45	C-4	2.66	10,700	d-S	29	(52)		52	74,000			Preheated and postheated
Joints in series C are same as those in A, except that the head of the rail and the base of the wide plate are planed (Fig 1). All seams worked as in series B.													
18 UNA	H-84		1.80			0	0	0	0	287,000	156 M	190 M	For details see Fig. 3 and Instructions, Bulletin 106
RWB Co.	H-85		1.91			0	0	0	0	314,000	78 M	114 M	
Average	2 joints		1.86			0	0	0	0	300,000	117 M	152 M	

* UNA Joint Rod 200.

Notation:
a — outside head seam.
b — Inside head seam (lip side).
c — Outside base seam.
d — Inside base seam.
N — north.
S — south.

For joint design, see Fig. 1.

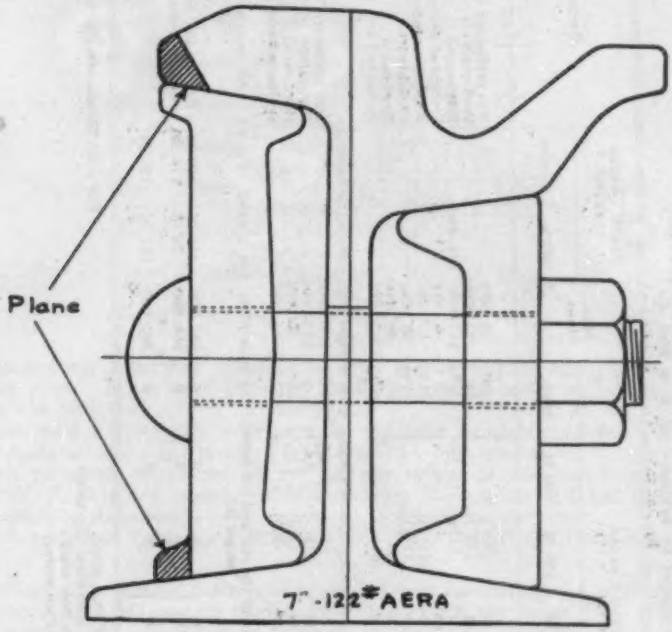
an accelerated degree the relative merits of pre-heating, post-heating, etc., as regards residual stresses in the rails.

4. Conclusions:

A. All the seam welds in these series of joints show evidences of having been made up with too high a welding current.

B. The lack of groove and ledge on the lip side of the rail was a further cause of poor seam welds.

C. The lack of a groove and ledge condition for the head seam welds on the wide plate, accounts to some extent for poor welds. In this connection it should be noted that an acute angle condition is never the best one for seam welding, whether by carbon arc or metal arc.



Section of test Joint
U.R & E Co. (Baltimore)
Fig. 1

D. Preheating the joint to a temperature of 600-800° F. is hardly to be considered good practice in the light of present knowledge. In the first place it is a more or less expensive and troublesome procedure, but above all, it must make conditions so uncomfortable for the welder that he cannot do his best work.

E. Working the seam welds with pneumatic hammers would unquestionably be good practice, if it could be done above the critical temperature. However, if the operation is carried out below this temperature (and it is very difficult to do otherwise), there is great danger of embrittling and damaging the weld metal. The embrittling effect on steel due to mechanical work is especially marked in the temperature range of about 570° to 700° F. (See "Metallurgy of Iron and Steel" by Bradley Stoughton).

F. Post-heating the entire joint to a temperature of 600 to 800° F. is also of doubtful value. There is ample evidence, however, from results obtained in

bar and butt weld practice, to believe that post-heating the rail bases at the ends of fishplates to the critical temperature, or some pre-determined lower temperature, will be of considerable advantage in relieving stresses in the rails at these points.

G. As far as can be ascertained at the present time, the best and most reliable joint welding has been accomplished by following the instructions as given in our Bulletin 106. These instructions involve the new "UNA-fying" Process. We would recommend that a series of joints be made up following these instructions as closely as possible.

BOSTON ELEVATED RAILWAY, BOSTON, MASS.

1. The following description of the test joints referred to in this report is taken from the letter dated October 3, 1924, from Mr. H. M. Steward to Mr. E. R. Alexander:

"We have made up ten sample joints for impact testing which we are shipping to you by freight prepaid. The joints are made up of two pieces of rail, each 16" in length, making the total length of joint 32"; rail section 7" girder, B. S. Co. section 122–407A with standard joint plates and no base plates. A soft steel insert 1/16" in thickness was placed between the rail ends and joints assembled under compression. Welding rod used was R. W. & B. Grade 200, 9/32" diameter. All joints were welded by the hand feed process known as Process 'B.'

The joints were made up as follows:

4 joints with no preheating or postheating.
2 joints preheated.
2 joints postheated.
2 joints preheated and postheated.

Top seams of all joints, double weld.

Base seams of all joints, single weld.

The number of inches of welding rod used for each seam was as follows:

Joints Nos. 1, 2, 6 *and* 7
No preheating or post-heating.

Joint No. 1		*Joint No.* 6	
Inside top	29"	Inside top	35"
Outside top	35"	Outside top	29"
Inside base	19"	Inside base	18"
Outside base	20"	Outside base	19"

Joint No. 2		*Joint No.* 7	
Inside top	32"	Inside top	36"
Outside top	28"	Outside top	35"
Inside base	18"	Inside base	19"
Outside base	18"	Outside base	19"

Joints Nos. 5 *and* 9
Preheated

Joint No. 5		*Joint No.* 9	
Inside top	34"	Inside top	44"
Outside top	27"	Outside top	43½"
Inside base	17"	Inside base	19"
Outside base	18"	Outside base	18"

Joints Nos. 3 *and* 8
Postheated

Joint No. 3		*Joint No.* 8	
Inside top	32"	Inside top	35"
Outside top	27"	Outside top	38"
Inside base	16"	Inside base	19"
Outside base	17½"	Outside base	20"

Joints Nos. 4 and 11
Preheated and Postheated

Joint No. 4		*Joint No. 11*	
Inside top	34"	Inside top	44"
Outside top	36"	Outside top	43"
Inside base	17"	Inside base	19"
Outside base	17"	Outside base	18½"

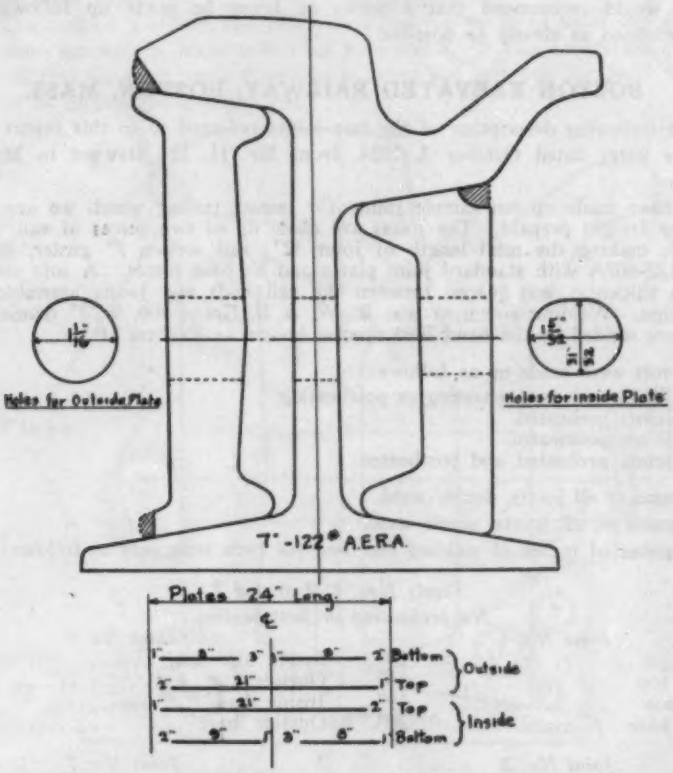


Fig. 2

"Our heating apparatus consisted of two Hauck torches one applied to either side of the joint. We had no accurate means of determining the temperature to which the rails were heated, but tin foil would readily melt when laid on the rail and we assume the temperature was between 600 and 800° F. Fig. 2 shows the cross section of the joint."

The method of testing is described in "Investigation of Seam Welded Rail Joints" (January 1924 issue of the Journal of the American Welding Society). The essential conditions of the test were as follows:

Weight of hammer	250 lbs.
Weight of anvil	2450 lbs.
Drop of hammer	10 inches.
Blows per minute	70
Support of joint	½ inch leather strip directly on anvil.
Total length of joint	32 inches.

2. Included in the summary of data, are the test data of joints H-84 and H-85 welded by the Rail Welding & Bonding Company for purposes of comparison. These joints were welded in accordance with instructions as noted in our Bulletin 106."

It must be kept in mind that the tests described in this Report were not intended to bring out the effects of pre-heating and post-heating on the rail itself, but rather on the seam welds. In order to determine the effects of pre-heating, post-heating, staggered plates, staggered seams, etc., as regards stresses in the rails, we have devised a means

SUMMARY OF REPEATED IMPACT TEST DATA

Rail joints welded by Boston Elevated Railway Co.

Group No. Proc.	Our No.	Your No.	Total rod,* lbs.	Seam Weld Cracks in Fish Plates						Max. blows	Plate Cracks Started		Remarks
				Started	Loc.	50 M	100 M	200 M	Max.		Wide	Narrow	
101 UNA	R-59	1	1.98	.....	.....	0	0	0	0	226,500	170 M	100 M	These joints were not pre-heated or postheated
	R-60	2	1.69	.....	.....	0	0	0	0	369,000	170 M	292 M	
	R-64	6	1.77	.....	.....	0	0	0	0	256,700	238 M	210 M	
	R-65	7	1.91	.....	.....	0	0	0	0	215,300	171 M	193 M	
Average 4 joints			1.84	.....	.....	0	0	.....	0	252,000	187 M	199 M	
102 UNA	R-63	5	1.69	12,600 cS	.....	32½"	(57½)	.....	57½	94,000	.....	.....	Preheated by means of Hauck torches
	R-67	9	2.18	4,300 b and d	.....	41	(63½)	.....	63½	79,500	.....	.....	
Average 2 joints			1.94	8,500	.....	37	(61)	.....	61	87,000	.....	.....	
103 UNA	R-61	3	1.63	6,400 dS	.....	7"	16½	45	50"	232,000	.....	.....	Postheated by means of Hauck torches
	R-66	8	1.97	102,800 dN	.....	0	0	23"	25½	221,000	.....	176 M	
Average 2 joints			1.80	54,600	.....	3½	8	34	38	227,000	.....	.....	
104 UNA	R-62	4	1.83	1,800 dN	.....	23"	(50)	.....	50	98,000	.....	.....	Preheated and postheated by means of Hauck torches
	R-69	11	2.18	85,700 bN	.....	0	23"	44"	44"	200,000	.....	.....	
Average 2 joints			2.00	43,800	.....	12	37	.....	47	149,000	.....	.....	
18 UNA RWB Co.	H-84	.....	1.80	.....	.....	0	0	0	0	287,000	156 M	190 M	For details, see Fig. 3 and Instruction Bulletin 106
	H-85	.....	1.91	.....	.....	0	0	0	0	314,000	78 M	114 M	
Average 2 joints			1.86	.....	.....	0	0	0	0	300,030	117 M	152 M	

* UNA Joint Rod 200.

Notation: a — outside head seam
b — inside head seam (tip side)
c — Outside base seam
d — Inside base seam
N — north
S — south
For joint design see Fig. 2

for holding joints 68" long on supports having a span of 60". It is recommended that further test joints be made of such length (68") that they can be tested on this wide span. The test will be a very severe one, but it will bring out in an accelerated degree the relative merits of pre-heating, post-heating, etc., as regards residual stresses in the rails.

3. Conclusions:

A. The four joints in Group 101 were excellent joints in every respect. The welding conditions for the head seams would have been very much better, however, had plates been used of the design recently adopted by the Boston Elevated Railway. In any event, these four joints gave ample evidence of the advantages of providing a groove for the head seams which are welded by the UNA process.

B. The joints which were preheated or postheated, or both preheated and postheated, by Hauck torches, for some reason, not definitely understood at present, did not give as good results as the joints in Group 101. In the case of the preheated joints, it is probable that the preheating made the working conditions so uncomfortable for the welder that he could not do his best work. In the case of the postheated joints, it may be that the seam welds had become embrittled by a too prolonged heating below the critical temperature, but no definite conclusions can be stated at this time.

C. While postheating the *entire* joint to a temperature of 600–800° F., is of doubtful value (in fact it appears at present to be actually harmful), there is ample evidence from results obtained in bar and butt weld practice, to believe that postheating the *rail bases* at the ends of the fishplates to the critical temperature, or to some predetermined lower temperature, will be of considerable advantage in relieving stresses in the rails at these points.

D. Judging from the results obtained in Groups 18 and 101 (for girder rails) and from similar results obtained on T-rail joints welded by the R. W. & B. Co. and also by the Denver Tramway Company, it would appear that at the present time the best practice in joint welding is to be obtained by following the instructions as given in our Bulletin 106. This practice involves the new "UNA-fying" Process.

APPENDIX B

OTHEOGRAPH*

By P. M. Gillilan†

The otheograph consists of one or more steel ties with indicators on each end which record the reaction of locomotives and cars on the track and shows the impulse of each wheel on the ends of every tie. It shows the following on a graphic record:

The amplitude and characteristics of both the vertical and transverse flange thrusts of all the wheels on each rail.

The running equalization and rolling characteristic of the locomotive and cars.

The comparative vertical and lateral flange thrusts at different speeds.

When installed in the main line it may be arranged to show the loading of every wheel, even in a long train.

It detects flat spots on wheels and shows on which wheel they exist.

It indicates any transfer of weight or tilting in the locomotive driving trucks and the extent of the transfer.

Description

Each otheograph tie consists of three principal parts which are the steel tie casting, the bottom and side springs, and the recording heads.

The tie casting for a standard 4-ft. 8½-in. track gage is 6 ft. 10 in. long and is the foundation to which the various parts are fastened. It is designed for strength and rigidity and yet is made as light as possible. To this cast-steel tie are fastened the supports for the bottom springs, the stops for holding the rails in place and a cross bar at each end which supports the recording heads. The tie turns up at the end and is machined to hold the side springs in place.

The main springs are flat, specially machined, tempered and ground. The pressure is applied at the center of the springs. The latter are uniformly one inch thick and rest on supports 20 in. apart which makes them a beam of uniform section supported at the ends with a concentrated load at the center.

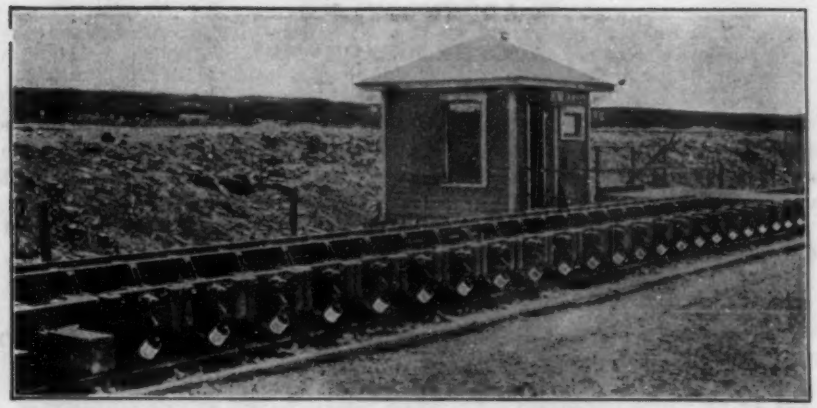
The maximum deflection of these springs is limited to ⅛ in. at the center. With a 100-lb. rail, two springs are placed under each rail and two set on edge in the end of the tie and opposite the head of each rail. The bottom springs are 6 in. wide and the side springs 4½ in. wide. Spacers are placed between each pair of springs at each end and at the center. Both sets of springs lie with their long axes parallel to the rail.

The recording heads are bolted to the cross bar on each end of the tie. Each head consists of a main frame casting, recording drum and two recording levers. The recording drum is set on the lower part of the casting at an angle of 45 degrees to the rail. This arrangement permits the two recording arms to operate on the same drum. The drum is revolved by a flexible wire cord wound in a groove around the base. The torque exerted is counterbalanced by a coil spring inside the cylinder which causes the drum to return when the tension is relieved. Two clips are hinged to the bottom casting of the drum to hold the recording paper. The drum is a brass cylinder, 4 in. long and 4 in. in diameter.

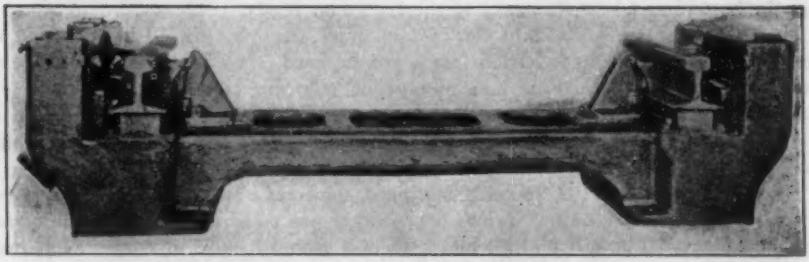
The two recording levers in each head casting are alike. The upper lever records the lateral, and the lower the vertical movement of the rail. Each consists of three principal parts, short radius arm, long radius arm and stylus arm. The short radius arm with a cam fastened to it is part of a machined piece about which the recording

* Extracted from article in Railway Age, August 16, 1924.

† Railway Engineering Department, General Electric Company, Schenectady, N. Y.



Otheograph Installation on Erie Test Track Showing 23 Fully Equipped Ties



Side View, Showing Location of Rails and Operating Mechanism

lever rotates. The long radius arm is made of very light steel tubing, copper plated, and is brazed to the machined piece. The aluminum stylus arm is hinged to the end of this long arm. Between the cam on the short radius arm and the side spring is an adjustable distance piece which transmits the movement from the center of the spring and rail to the recording arm. The cam rolls on the flat hardened steel surface of the distance piece and is designed to give a compensating radius to the short arm in order that the multiplied record on the paper will be maintained constant. The arm is built to give a ratio of eight to one. In order to set the stylus for the zero line on the record, the distance piece is made adjustable. The short radius arm is held tight against the distance piece by a retriever spring, which may be set to the proper pressure by an adjusting screw. The spring pressure is so slight that the opposing effect on the main side springs is negligible.

The aluminum stylus arm carries a small brass stylus pin which is held in contact with the record paper by the action of two springs. One is a coil tension spring which holds the arm against the drum and the other a flat cantilever spring which holds the stylus pin at the proper pressure on the paper. The stylus pin is guided by a hardened steel bushing set in the aluminum arm. The end of the bushing next to the paper is polished so that it can rub on the record without tearing. Metallic coated paper, 4 in. wide and 16 in. long is used for the records. This paper shows a good distinct black mark when the brass stylus passes over it. It shows marks of brass, copper, silver, nickel, etc., but is not affected by steel.

When changing the records after a test run, the stylus arms can be folded back out of the way. These arms maintain a position nearly parallel to the long radius arm and are held there by the same coiled spring which holds them against the recording arm.

Records

The otheograph records show the comparative effect on the rails for each wheel, equalization of axle weights, and lateral thrusts which give an indication of the tracking qualities. The slope of the impact peaks gives the rate of speed of the blow on the rail. The records also indicate the dynamic augment when comparing an engine at slow speed with the higher speed record.

A full set of otheograms is made when the locomotive or train passes over the otheograph. On each side of the track the successive otheograms show the impulse of the wheels on the rail at each tie. The lower curve of each record shows the vertical pressure of the wheels. The upper curve shows the lateral or flange thrusts of the train wheels. The part of this curve above the datum line is due to stressing the rail when the wheel is shifted toward the center of the track and has no calibration value. The upper and lower curves register together so that the lateral effect of a wheel is directly opposite the corresponding vertical impulse. The record of the leading wheel of the train is always at the left end of the otheogram. This is independent of the direction of the train movement over the otheogram.

The record from a slowly moving locomotive shows the equalized distribution of the weight and serves as the basis of comparison with a record taken at a higher speed. The effect of side thrust in changing the vertical component of the locomotive and any variation due to dynamic unbalance is definitely indicated. Every impulse of the wheels on the rail appears on the otheograms, even the effect of a flat spot on a wheel or any slight unevenness in the matching of the rail joints.

COMMENTS OF MANUFACTURERS OF JOINTS

Comments by H. F. A. Kleinschmidt, Lorain Steel Co.

It should be noted in Mr. Miller's discussion of the resistance weld as revealed in the fractures of the bar weld joints, that a weld is discussed which is not made in accordance with the best practice for welds of this type. In the bar weld joint it is more essential that the bars be as hot as possible when the end welds are being made in order that the shrinkage of the bars on cooling will draw the abutting rails tightly together than it is to produce a good weld at this point. Pressure is therefore not held on the center weld, as it is a very rare occurrence to have a joint break through the bars and center weld in actual practice (where they all broke in the tests), and which fractures were examined by Mr. Miller. We are more concerned with having the bars as hot as possible at the center than we are to produce a good weld here as this weld is subjected to practically no strains and its object is simply to prevent independent end movement of the rails. This weld is really made incidentally to heating the bars at the center so that they will be in an elongated state before the ends of the bars are welded to the rails. Had the end welds been examined, (none of which broke in the tests), a different story would have been told, as these welds are held under a heavy pressure while cooling which has the same effect as hammering or forging the steel and results in a remarkably strong, tough, weld.

Comments by R. B. Fehr, Rail Welding & Bonding Co.

1. (Referring to foot-note at bottom of page 12.)

"The Bureau of Standards very properly points out that during the tensile tests the joints were subjected to bending stresses because of the lack of coincidence of the center of resistance of the welded rail section and the center of

gravity axis of the rail. From careful measurements made on joints before and after they had been tested in tension, it is apparent that the cause of rail failure, instead of seam failure, in many of the tensile tests, was due primarily to the fact that these tensile tests were really *combined tension and flexure tests.*

"As also pointed out by the Bureau of Standards, there is some 'notch' effect due to the starting of the weld and residual internal stresses set up by the process of welding. However, such notch effect as may exist in seam welded joints made according to recommended practice can not be particularly harmful; otherwise, the severe drop tests made at the University of Illinois would have given very low results, as the drop test is particularly useful in showing up a notch effect. As a matter of fact, the seam welded joints, particularly those made by improved practices involving pre-heating, or a combination of staggered plates, staggered seams, pre-heating and post-heating by the long carbon arc, showed up so well under the drop tests in comparison with other types of joints, that it can be concluded that there is no seriously harmful notch effect in seam welded joints that are made in accordance with recommended practice."

2. (Referring to foote-note at bottom of page 78.)

"The statement 'not welded at bottom of groove' is correct, but it should be interpreted in the light of the following: No seam welds made by the UNA Process will be found welded at the bottom of the groove. The groove and ledge condition for welding the head seams was designed to produce easy welding conditions for the carbon arc and to enable the operator to obtain a large area of fusion between the seam metal and rail and between the seam metal and plate. In all cases, the groove has been made purposely somewhat deeper than it was expected the weld could be made, in order to facilitate the action of the carbon arc."

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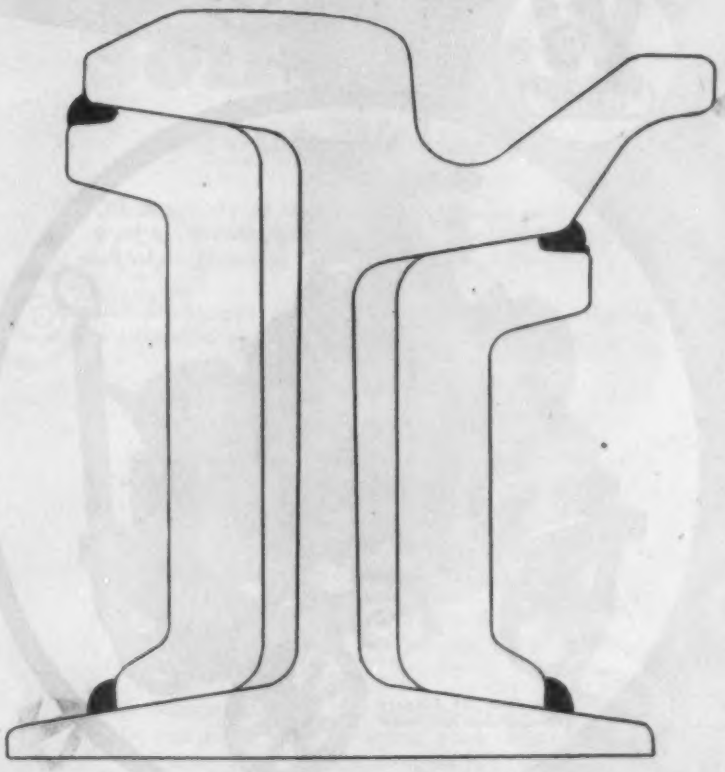

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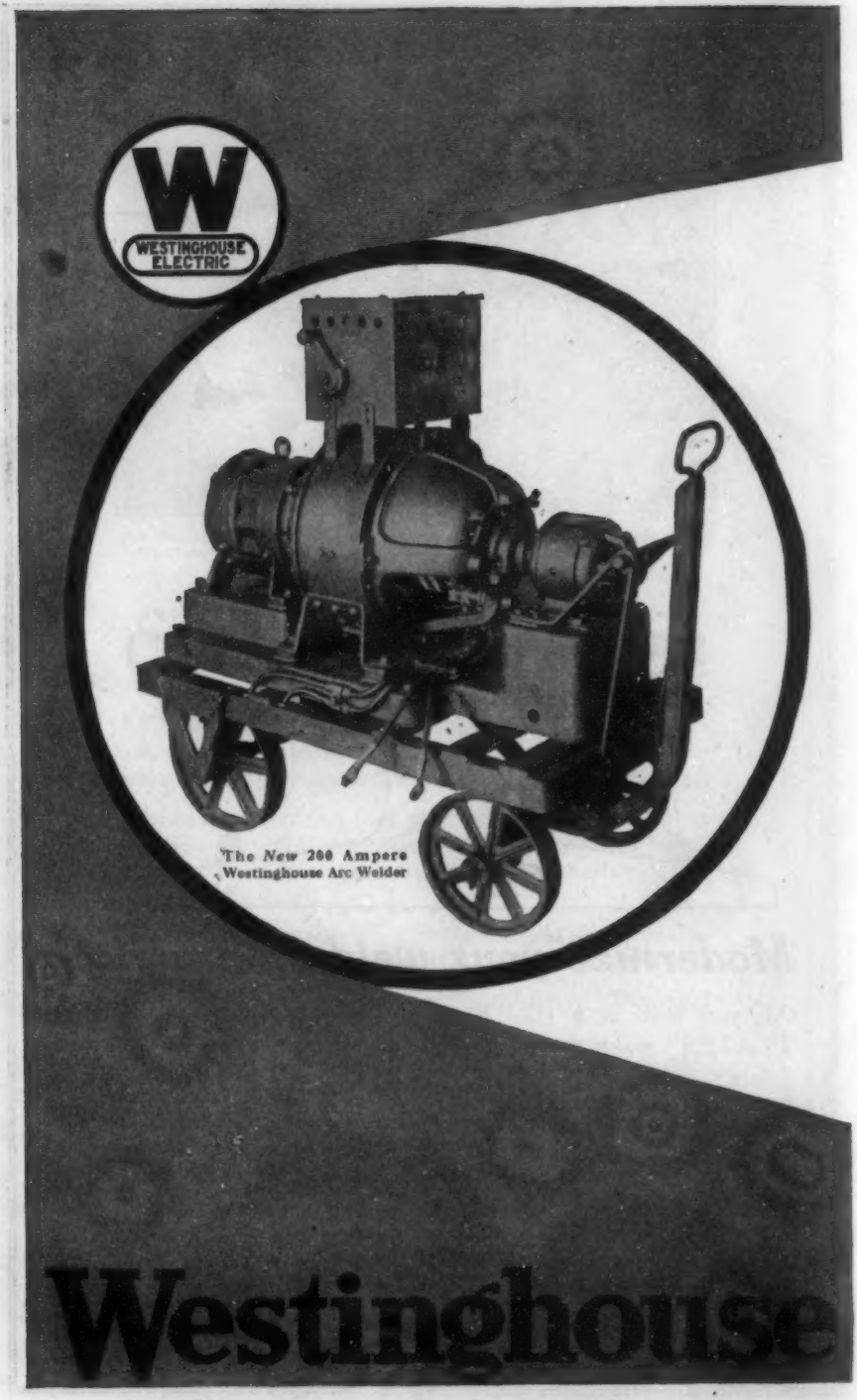
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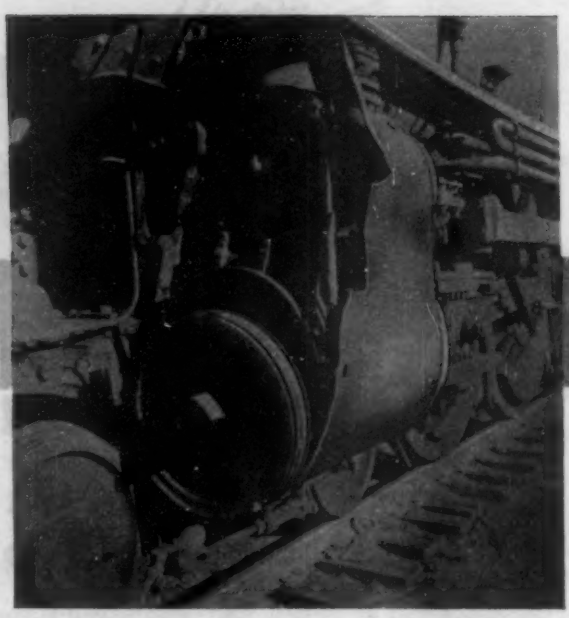
AR—A.C. D.C.—200 amp.—Single Operator Stationary
Length, 38 inches Diameter, 17 1-8 inches
Net weight, 760 pounds Shipping weight, 840 pounds

AR—A.C. D.C.—200 amp.—Single Operator Portable
Length, 38 inches Width, 24 inches Height, 32 inches
Net weight, 680 pounds Shipping weight, 805 pounds



A broken engine cylinder which was later reclaimed by welding.

417 Engine Cylinders Reclaimed Without One Failure

When you consider that a new cylinder would cost $1100, not including cost of installing, and that a fair average for welding is $260, this record becomes even more impressive.

Analysis of the cost of a typical job shows:

Cost of dismantling	$28.00
Cost of valve chamber and cylinder rings	35.00
Cost of chipping, studding and setting rings in place ready for welding	25.00
Labor cost for welding	108.00
Labor cost for machining	8.00
Cost of electric power	22.00
Cost of Electrode material	30.00
TOTAL	$256.00

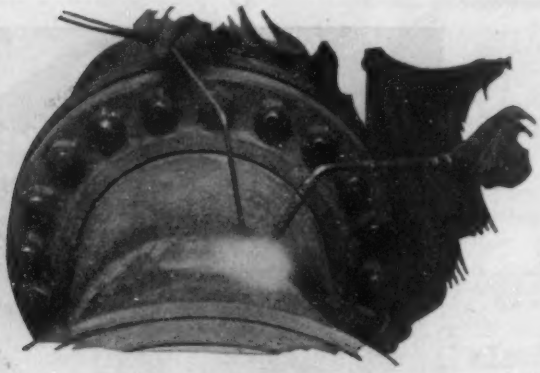
The repair of broken cylinders is only one of the many jobs which are welding performs in railroad shops. The G-E Arc Welder is a money-saving tool of vast importance to you.

The G-E Arc Welder gives 24-hour service day after day. It can be readily adapted to light or heavy duty work. It is simple, and easy to operate.

There should be no doubt of the value of a tool that does these things. The welding specialist in the nearest G-E office will gladly answer all your questions.

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., SALES OFFICES IN ALL LARGE CITIES



The purest iron

makes the quickest, most dependable weld

Welding men have found that Page Welding Rods and Electrodes made from commercially pure Armco Ingot Iron, flow more freely and assure the most uniform deposit of dense, clean metal.

Result: reduction of the labor cost per job to a minimum—and better welds.

Armco Iron for welding rods is the recognized standard — guaranteed 99.84% pure. Page Rods conform to A.W.S. specifications. Their cost is so small in comparison to the results obtained it always pays to insist on their use.

PAGE

ARMCO Ingot Iron

WELDING WIRE *and* ELECTRODES

PAGE High Carbon

Gas Welding Wire and Electrodes

The harder the welding job, the more important the welding material. For difficult steel welding use Page High Carbon Rods—save welding time and insure the success of the weld.

Hardness tests indicate that surfaces welded with Page High Carbon Steel have wearing qualities fully equal to those of the base metal.

To identify Page High Carbon Rods—look for the red tag and red ends.

PAGE STEEL & WIRE CO.

Bridgeport, Connecticut

District Sales Offices, Chicago, New York, Pittsburgh, San Francisco. An Associate Company of American Chain Co., Inc., of Bridgeport, Conn.

Plants and warehouses in 87 cities make it possible for 22 District Offices always to fulfill delivery promises for

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DISSOLVED ACETYLENE

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31 Plants — 60 Warehouses — 22 District Sales Offices

Why should you use Oxweld welding rods?

DIRT in the weld can be seen by an alert operator and by careful puddling he will be able to work it to the surface and remove it.

This work is tedious and takes time. And the added time will soon equal the money supposedly saved in buying cheap and inferior welding rods.

Poor welding rods might look like good ones—except under a microscope. Then the particles of dirt or "inclusions" between the crystals of metal are seen clearly. And this dirt is a direct cause of weakness in welds.

Oxweld engineers are not content with specifying merely the chemical composition of Oxweld welding rods. They go farther. All Oxweld rods are carefully tested. Steel, cast iron and non-ferrous rods are first flame tested to determine their welding qualities, with special attention given to eliminate any showing "inclusions." The test of chemical composition is then conducted. As a final check of steel and cast iron rods, coupons are welded and undergo a pulling test for tensile strength. These tests for physical properties are the most important, but only rods which pass all the tests are approved for shipment to customers.

To obtain better welds, buy better rods—Oxweld rods.

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Chicago - - - - - - - - - - - - - - 3642 Jasper Place
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WELDING AND CUTTING APPARATUS

WORLD'S LARGEST MANUFACTURERS OF WELDING AND CUTTING EQUIPMENT

ACETYLENE FROM CAKES

Carbic low pressure, portable generator. Weight charged—200 lbs.
Listed as standard by Fire Underwriters' Laboratories.

The most modern, efficient and safest source of acetylene supply—Carbic CAKES.

Not an experiment. Hundreds of Carbic generators using Carbic are in daily use on all kinds of welding and cutting work.

The use of Carbic Cakes permits an ease of handling, a convenience and a safety not otherwise obtainable.

Acetylene from Carbic costs less than one-half as much as compressed acetylene and only a few drums of cakes carried in stock insure a large supply of gas on hand at all times.

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CARBIC MFG. CO.

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JAR

ROEBLING
Welding Wire

Conforms to the specifications of the American Welding Society

Exacting tests have proven the reliability of Roebling Welding Electrodes. They are uniform throughout and make the strongest welds with the least trouble in welding.

John A. Roebling's Sons Company
TRENTON, NEW JERSEY

Rail Welding in the Electric Railway Field

The problem of combining low initial cost with the elimination of future maintenance

The Thermit Insert Rail Joint has solved the question in its own particular field, by affording a means of joining rail by which the initial cost is kept as low as by any other method, and the cost of maintenance kept even lower—so low, in fact, that it is practically nil.

The initial cost of the Thermit joint is low, compared with other methods because

(*a*) It does away completely with the cost of plates, bolts and bonding.
(*b*) It enables the track force to work efficiently, with no idle time.
(*c*) It requires a minimum of outside sources of power.
(*d*) It is possible to use a lighter rail than would otherwise be required, for the usual weak point, the end of the rail, is completely eliminated.

It does away with maintenance because

(*a*) The joint lasts as long as the rail itself.
(*b*) There is no digging of pavement later on to tighten loose plates.
(*c*) The absence of pounding at the joint protects the pavement—no patching—no unsightly gaps and holes on the right of way.
(*d*) No current losses through defective bonding.
(*e*) No shock to rolling stock every sixty feet, as there is on unwelded tracks.
(*f*) No replacements—no worry of any sort about your track.

Thermit Insert Rail Welds have stood the test of time.

"The First Cost is the Last Cost—Maintenance Nil."

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A WELDING MACHINE YOU CAN DEPEND UPON UNDER MOST TRYING CONDITIONS

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No Exciter—The welding generator is self-exciting.

Excellent welding characteristics throughout entire range.

Micrometer adjustment of welding current from 50 to 300 amperes for continuous service.

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